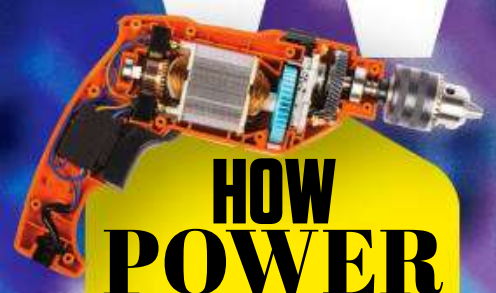
EXPLORE THE CHANNEL TUNNEL

HOW IT WORKS

AMAZING SPACE ROBOTS OF THE FUTURE



HOW POWER TOOLS WORK

HOW TO GROW MEAT IN A LAB

WHAT IS AN AI CHATBOT?

HOW ARTIFICIAL INTELLIGENCE CAN CREATE ART, WRITE ESSAYS AND EVEN HAVE A HUMAN CONVERSATION WITH YOU

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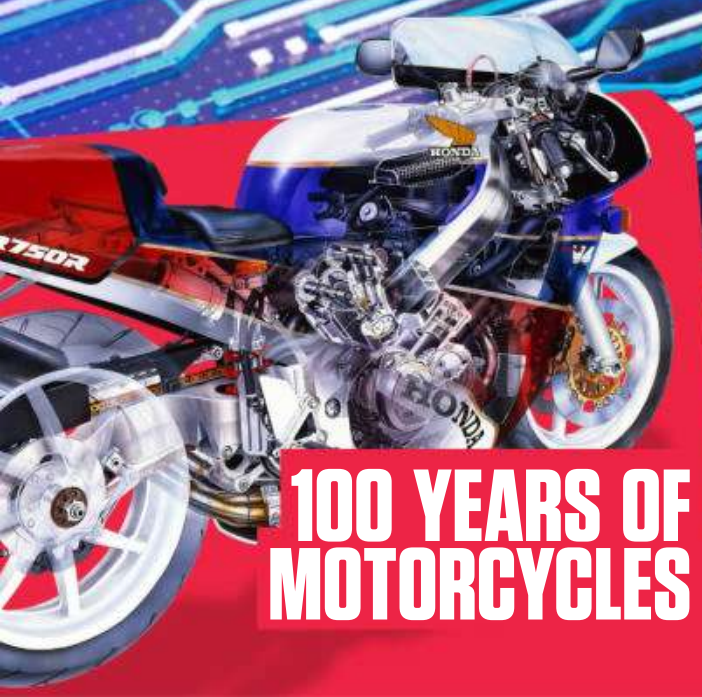
WHAT IS A ZOETROPE?

HOW E-INK WORKS

WHAT DOES NASA DO WITH MOON ROCKS?



100 YEARS OF MOTORCYCLES

WHY ARE SUPERCELL STORMS SO POWERFUL?

SEE INSIDE A CONSTRUCTION CRANE

FROM FISH TO HUMAN: EVOLUTION EXPLAINED

FUTURE
ISSUE 180

Made from plastic waste at risk of polluting the ocean

The new **Sistema® Ocean Bound Plastic collection** is perfect for transporting your lunches and drinks to and from school. The range includes two bottles and three snack and lunch boxes.

It is durable and versatile meaning it can withstand wear, pressure or damage, and fits perfectly into your school backpack. It can be reused, helping to cut down the number of single-use plastic containers and bottles thanks to its environmentally friendly design.

What is Ocean Bound Plastic?

Generated within a 50km radius of coast lines[1], ocean bound plastic refers to plastic waste that has been incorrectly disposed of on land, shores, waterways and river areas, which poses a risk of polluting the ocean. It is currently estimated that ocean bound plastic generates 80% of plastic marine litter.[2] Plastic waste that is thrown away correctly in landfills or organised dump sites is not categorised as ocean bound.

To learn more, visit:
www.sistemaplastics.com/uk/sustainability

Made using up to 35% of recycled plastic found in the ocean.

Food-safe & BPA free

Made using up to 50% of recycled plastic found in the ocean

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Available from Sainsbury's

WELCOME

Issue 180

ChatGPT
Examples
"Explain quantum computing in simple terms" →
"Got any creative ideas for a 10 year old's birthday?" →
"How do I make an HTTP request in Javascript?" →
Capabilities
Remembers what user said earlier in the conversation
Allows user to provide follow-up corrections
Trained to decline inappropriate requests
Limitations
May occasionally generate incorrect information
May occasionally produce harmful instructions or biased content
Limited knowledge of world and events after 2021
Free Research Preview: ChatGPT is optimized for dialogue. Our goal is to make AI systems more natural to interact with, and your feedback will help us improve our systems and
MacBook Pro

"They're capable of some truly astonishing stuff, including having a surprisingly complex and human-like conversation"

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What is an AI chatbot?
PAGE 26

Technology news has been buzzing with stories of the latest developments in artificial intelligence for the last few years, but stories have mostly been about how AI has been used by experts to decipher an ancient language, find new medicines or piece together the genome of a species. Recently, however, AI has been served up to ordinary people like you and me in the form of chatbots, accessible through an internet browser. And they're capable of some truly astonishing stuff, including having a surprisingly complex and human-like conversation and creating original artworks according to your instructions. How do they do that? It involves sophisticated programming and hardware. Learn how AI chatbots work on page 26. Enjoy!

Ben Biggs
EDITOR

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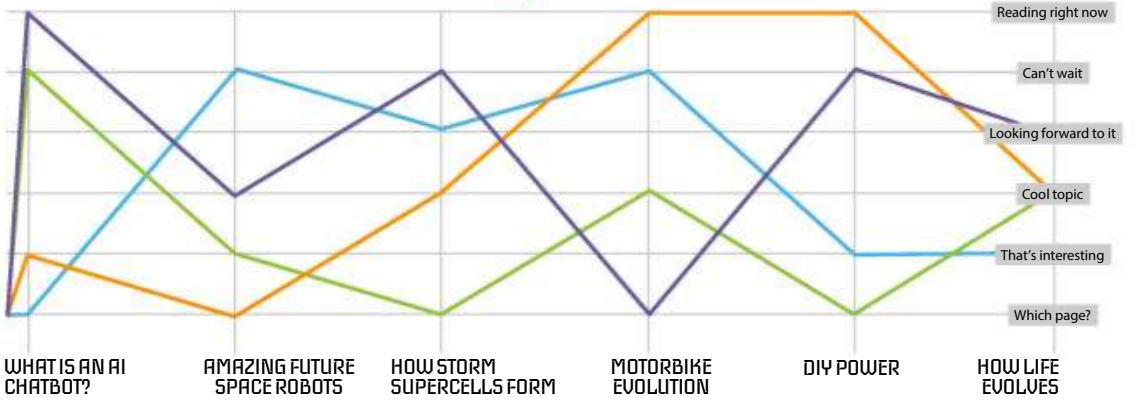
WHAT WE'RE ANTICIPATING



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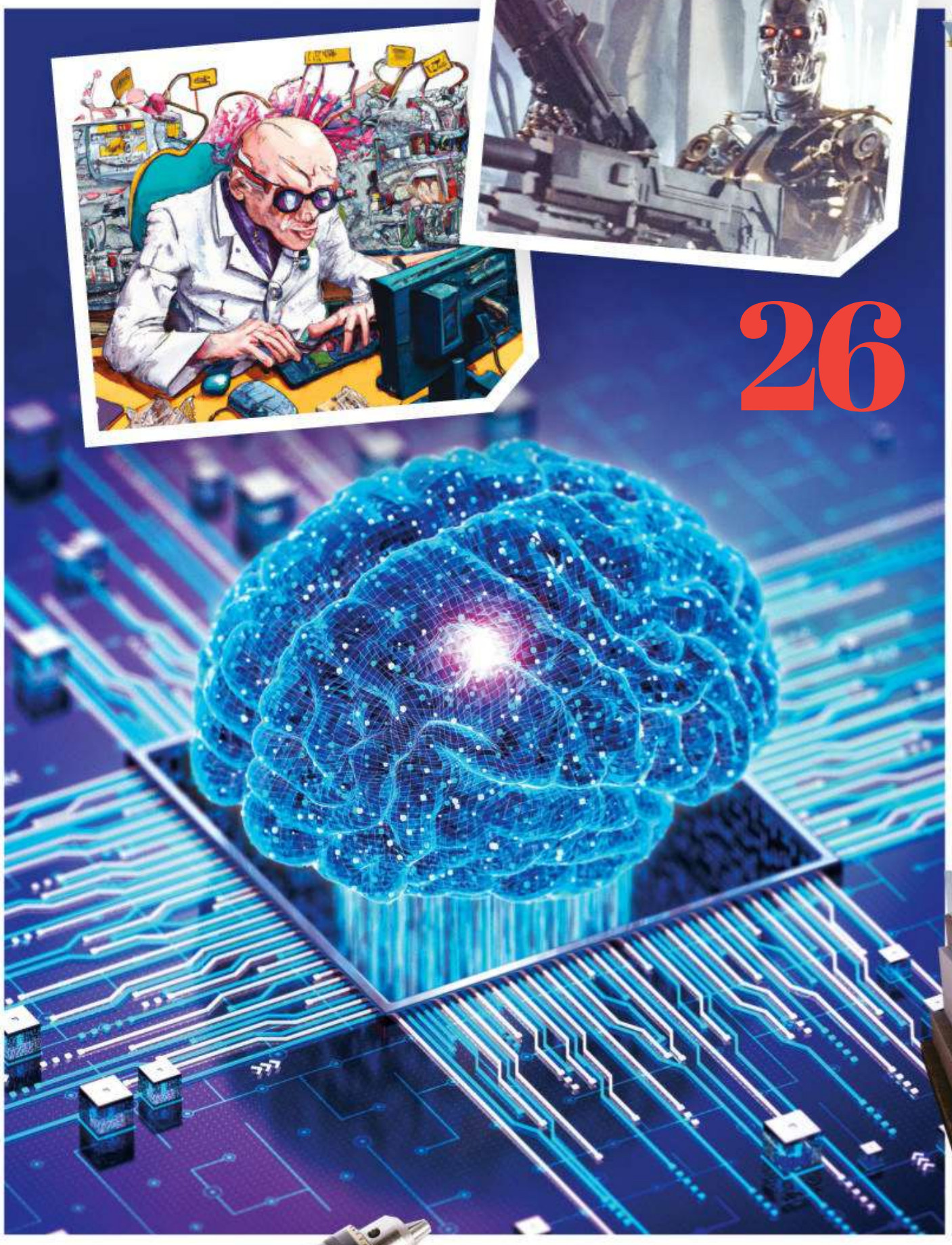

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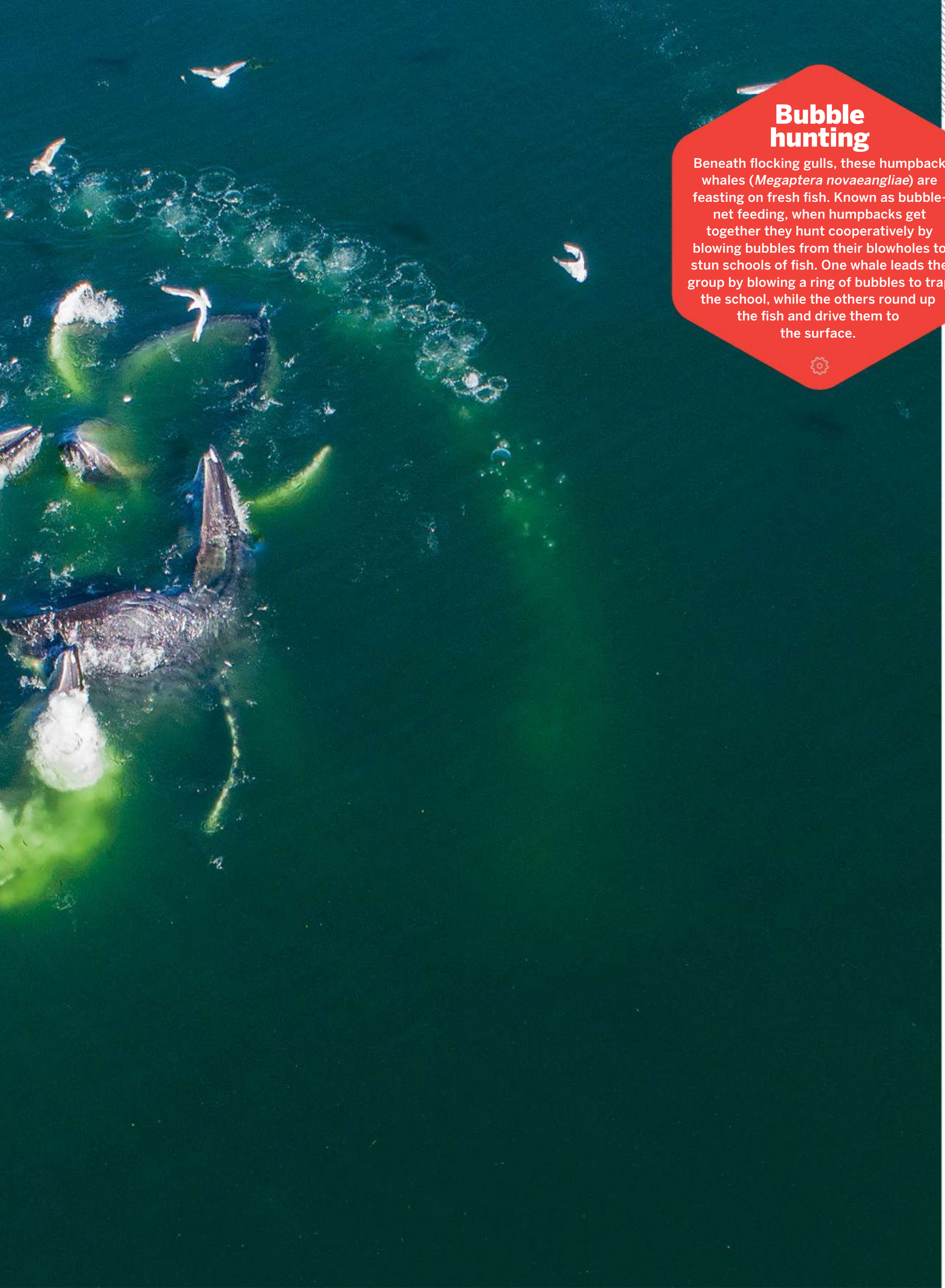


Bubble hunting

Beneath flocking gulls, these humpback whales (*Megaptera novaeangliae*) are feasting on fresh fish. Known as bubble-net feeding, when humpbacks get together they hunt cooperatively by blowing bubbles from their blowholes to stun schools of fish. One whale leads the group by blowing a ring of bubbles to trap the school, while the others round up the fish and drive them to the surface.

© Getty

Snapping skyscrapers

Margaret Bourke-White was an American photojournalist and one of the first female war correspondents during World War II. In this striking image, Bourke-White is focusing her camera on the metropolis of New York City while perched on the head of one of the eagle-head gargoyles at the top of the Chrysler Building, hundreds of metres from the ground. This image was shot by artist Oscar Graubner in 1935.

© Alamy

Fungal handshake

This is a scanning electron microscope image of *Penicillium chrysogenum*, a species of fungus that can be found growing on salted food products in damp and warm conditions. Its hand-like appearance is created from its segmental anatomy, starting as tendon-like hyphae and finger-like sterigmata (orange) and ending with spores at the 'fingertips' (purple).

© Alamy

Peering behind bars

This otherworldly view shows barred spiral galaxy NGC 5068. Captured by the James Webb Space Telescope, it shows the green gas and dust bars, roaring red stars and bright core of the galaxy in brilliant detail. At its core – the bright-white strip in the top left – are thousands upon thousands of stars burning bright, the data from which scientists are using to better understand how stars grow and evolve.

© ESA/Webb, NASA & CSA, J. Lee and the PHANGS-JWST Team

SPACE

Perseverance rover finds organic molecules on Mars

WORDS **CHARLES Q. CHOI**

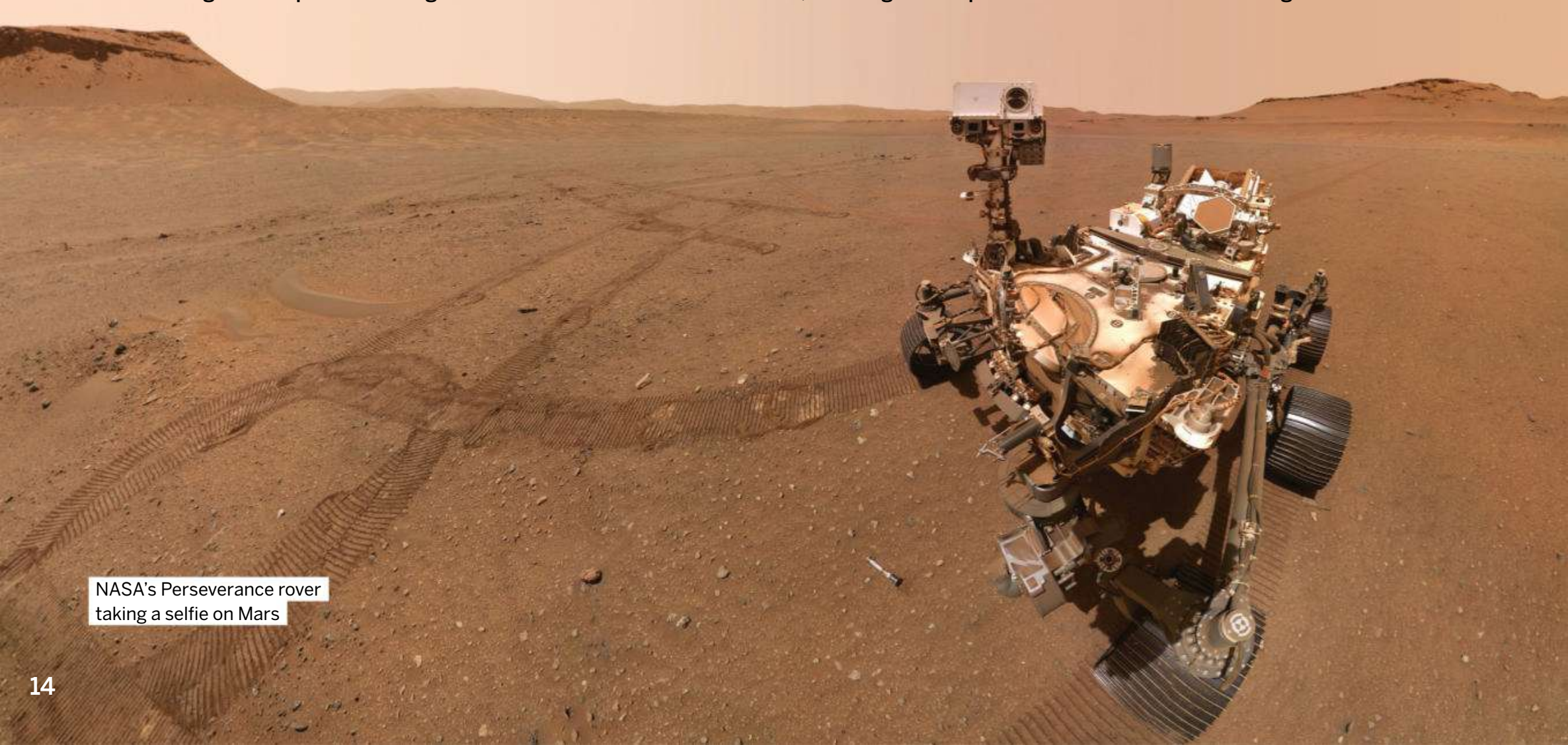
NASA's Perseverance rover has found a diverse menagerie of organic molecules in a Martian crater. Organic compounds are molecules composed of carbon, and often include other elements such as hydrogen, oxygen, nitrogen, phosphorus and sulphur. Previously, scientists had detected several types of organic molecules of Martian origin in meteorites blasted off Mars by cosmic impacts that landed on Earth, and in Gale Crater on the Red Planet.

"They are an exciting clue for astrobiologists, since they are often thought of as building blocks of life," said Sunanda Sharma, a planetary scientist at the California Institute of Technology. "Importantly, they can be created by processes not related to life," Sharma emphasised. As such, investigating what organic molecules exist on the Red Planet and how they were created is key to understanding what may or may not be linked to life on Mars. "As planetary scientists and astrobiologists, we are very careful with laying out claims – claiming that life is the source of organics or possible biosignatures is a last-resort hypothesis, meaning we would need to rule out any non-biological source of origin," Sharma said.

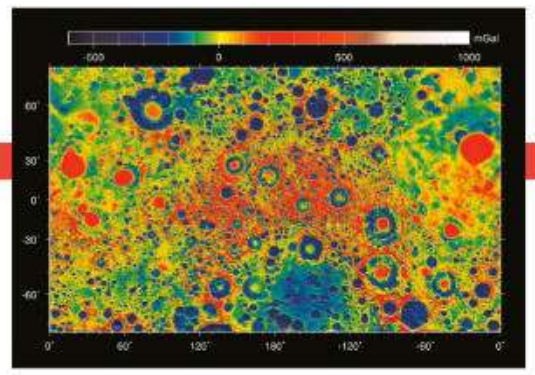
In a new study, Sharma and her colleagues analysed data from Perseverance. In February 2021, the rover landed within Jezero Crater, the site of an ancient lake basin that prior work suggested displayed high potential for past habitability. The crater floor also possesses clays and other minerals that may preserve organic materials. Specifically, the scientists examined data from the Scanning Habitable Environments with Raman and Luminescence for Organics and Chemicals (SHERLOC) instrument onboard Perseverance. The researchers focused on SHERLOC data from Máaz and Séítah, two rock formations on the Jezero Crater floor. When ultraviolet light from SHERLOC illuminates organic compounds, they can glow much like material beneath a blacklight. The fingerprint of wavelengths in the glow from a molecule can help identify it.

Sharma and her colleagues found signs of organic molecules in all ten targets that Perseverance drilled into, covering a timespan from at least 2.3 to 2.6 billion years ago. These "point to the possibility that building blocks of life could have been present for a long time on the surface of Mars, in more than one place," Sharma said. The scientists discovered evidence of many different classes of organic molecules. These occurred in a variety of patterns in space within Máaz and Séítah, suggesting they might have originated from a number of different minerals and mechanisms of formation. These compounds mostly appeared connected to minerals linked to water.

"Seeing that the possible organic signals differ in terms of type, number of detections and distribution between the two units of the crater floor was surprising and exciting," Sharma said. "That opens the possibility of different formation, preservation or transportation mechanisms across the crater and, more broadly, the surface of Mars." The scientists could not identify specific organic molecules. "To confirm the presence of organics and their specific types, we would need the samples to be returned to Earth," Sharma said. "That's our goal."



NASA's Perseverance rover taking a selfie on Mars



Recent observations of the Moon's far side revealed a strange heat anomaly that could be a long-dead volcano

SPACE

SCIENTISTS DISCOVER A HUGE HOT BLOB ON THE MOON

WORDS **STEPHANNIE PAPPAS**

Scientists have discovered a blob of heat on the far side of the Moon. This is likely caused by the radiation from a huge buried mass of granite. "This is more Earth-like than we had imagined can be produced on the Moon, which lacks the water and plate tectonics that help granites form on Earth," said Matt Siegler of the Planetary Science Institute, Arizona.

Using data from the Chinese lunar orbiters Chang'e 1 and 2 and NASA's Lunar Prospector and Lunar Reconnaissance Orbiters, researchers found an area about 31 miles across where the temperature is about ten degrees Celsius warmer than the surroundings, below a 12.4-mile diameter spot that is rich in silicon, thought to be a collapsed volcanic crater. It last erupted 3.5 billion years ago, but magma is likely still below the surface. "This find is a 31 mile-wide batholith... a type of volcanic rock that forms when lava rises into the Earth's crust, but does not erupt onto the surface," said Economos." El Capitan and Half Dome in Yosemite are examples of similar granite rocks which have risen to the surface."

"People don't think twice about having a granite countertop," said Stephen M Elardo, geochemist at the University of Florida. "But geologically speaking, it's quite hard to make granite without water and plate tectonics, which is why we really don't see that type of rock on other planets. So if this finding by Siegler and colleagues holds up, it's going to be massively important for how we think about the internal workings of other rocky bodies in the Solar System."

PLANET EARTH

Swirls of liquid iron may be trapped inside Earth's core

WORDS **STEPHANIE PAPPAS**

Earth's solid inner core may not be solid after all. New research based on the faint echoes of earthquake waves bouncing back to Earth's surface from the depths of the planet suggests that the inner core is more varied than previously appreciated. This indicates that the inner core, which grows about a millimetre each year, may have grown faster in earlier times. What's more, there may be swirls of liquid iron trapped in the core.

"A long time ago, the inner core grew really fast," said Keith Koper, a seismologist at the University of Utah. "It reached an equilibrium, and then started to grow much more slowly. Not all of the iron became solid, so some be trapped inside."

Earth's inner core is a solid ball of mostly iron and nickel. Measuring about 1,520 miles, this spins inside the outer core, an ocean of molten iron and nickel about 1,400 miles thick. The churn of the metal at Earth's centre is what creates the planet's magnetic field. Over time, the outer core has crystallised, but scientists know little about how quickly this process has occurred, which raises questions about Earth's magnetic field. Koper and his team used data from 20 seismometers to measure earthquake waves and monitor for nuclear-weapons testing. They focused on waves triggered by earthquakes of magnitude 5.7 or above, which are large enough to vibrate down to the inner core, sending a faint echo to the seismometer. There were 2,455 earthquakes in the dataset.

"This signal that comes back from the inner core is really tiny," Koper said. "The size is about on the order of a nanometer. What we're doing is looking for a needle in a haystack. So these baby echoes and reflections are very hard to see." The new study found that the core's composition was 'inhomogeneous', or varied. In other words, the inner core didn't solidify smoothly, and is made up of a patchwork of different textures. "For the first time, we confirmed that this kind of inhomogeneity is everywhere inside the inner core," said Guanning Pang, a postdoctoral researcher at Cornell University. Seismic waves scatter more the deeper they penetrate, Koper said, indicating an increasing amount of variability closer to Earth's centre. This could be related to the changing rate of solidification of the core over time.

Did you know?

Iron is the second most abundant metal on Earth

Earth's inner core may be more varied in texture than previously understood

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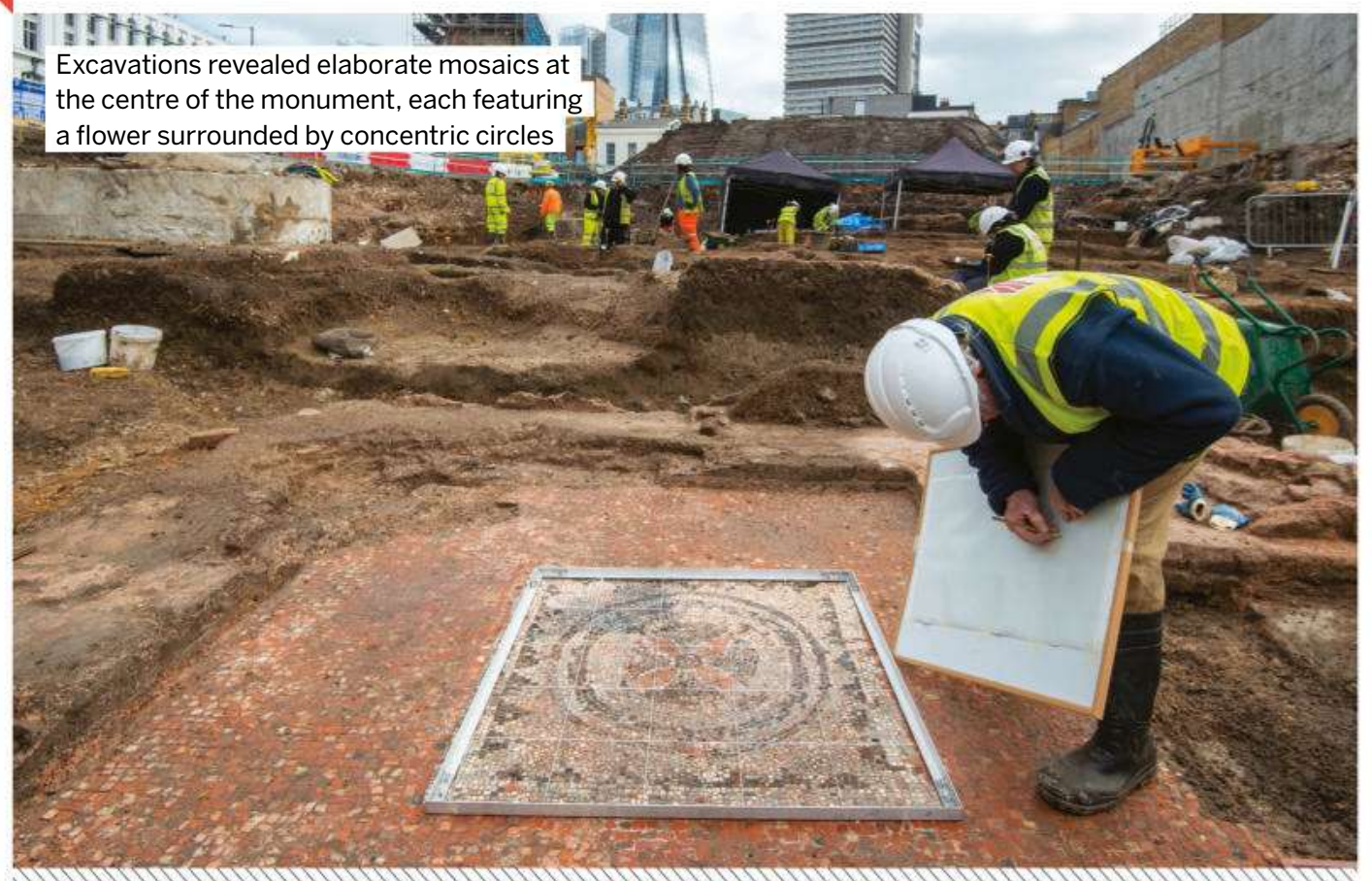


Excavations revealed elaborate mosaics at the centre of the monument, each featuring a flower surrounded by concentric circles

ARCHEOLOGY

Roman mausoleum discovered in the rubble of a London building site

WORDS **SASCHA PARE**

A completely unique, 2,000-year-old Roman mausoleum that has emerged from the rubble of a development site in central London is the most intact ever discovered in the UK The monumental tomb, of which low walls, entrance steps and interior flooring remain, is bejewelled with two mosaics composed of small red tiles, each featuring a flower enclosed in concentric circles. More than 100 coins were also strewn across the tomb's floor. Archeologists only found the second mosaic when they dug beneath the first one. This indicates that the mausoleum floor was raised at least once while it was still being used for burials.

The discovery, which is nestled within the city's central Southwark area, "provides a fascinating window into the living conditions and lifestyle in this part of the city in the Roman period," said Antonietta Lerz, a senior archeologist at The Museum of London Archeology (MOLA). A video reconstruction of the mausoleum's interior reveals how the tomb may have been laid out and decorated during Roman times.

Roman invaders under Emperor Claudius founded London, or Londinium, around 47 AD and ruled the city through to the early 5th century, when dwindling military resources and incursions across the rest of the empire forced their withdrawal from Britain. The recent excavation bears the marks of this decline. "This relatively small site in Southwark is a microcosm for the changing fortunes of Roman London – from the early phase of the site where London expands and the area has lavishly decorated Roman buildings, all the way through to the later Roman period when the settlement shrinks and it becomes a more quiet space where people remember their dead," Lerz said.

The mausoleum would have originally housed coffins and other burial artefacts, but none were recovered from the structure itself. However, the excavation site around the monument yielded Roman-era items belonging to more than 80 burials, including copper bracelets, glass beads, pottery and a bone comb. Archeologists will now examine these recovered items to better understand central London's Roman past.

Only the wealthier members of society would have had access to the mausoleum, which may have been used as a family tomb or belonged to a 'burial club', requiring a monthly fee to secure a future grave. What remains of the structure indicates that it was a two-storey building with large buttresses in the corners for support. The high walls were probably dismantled for reuse elsewhere during the medieval period. Inside, a raised platform cemented with pink mortar containing crushed bits of pottery and brick, a widely used Roman building material known as 'opus signinum', designates where the burials would have taken place around three sides of the mausoleum.

HEALTH

SCIENTISTS DISCOVER WHERE THE MICROPLASTICS HUMANS INHALE END UP

WORDS **BEN TURNER**

Humans may be inhaling a credit card's worth of toxic microplastics every week. In 2019, a team of scientists estimated that up to 16.2 bits of microplastic enter our airways every hour. Now, researchers have built on these findings to figure out how the plastic moves around our respiratory systems.

Microplastics are tiny chunks of plastic debris measuring less than five millimetres. There have been few studies into how toxic microplastics impact human health. However, recent studies suggest these tiny particles could pose serious health problems. Now, researchers have used a computer model to find the regions of our airways most impacted by breathing in microplastics. It did this by analysing where they travel in our airways, and where they're deposited.

By analysing this under slow and fast breathing conditions with three plastic shapes – spherical, tetrahedral and cylindrical – researchers found that the biggest chunks of microplastic were most likely to get lodged. The places these tended to go were in the upper airways, such as the nasal cavity and back of the throat. The researchers say their next steps will be to investigate how plastics are deposited inside human lungs.

Researchers estimate that humans inhale a credit card's worth of microplastics a week

ANIMALS

Scientists make the world's first genetically modified snakes

WORDS JENNIFER NALEWICKI

For the first time ever, scientists have created genetically modified snakes. The CRISPR-edited reptiles are providing new insight into how corn snakes (*Pantherophis guttatus*) develop their precisely patterned scales. Much like feathers on birds or hairs on mammals, snake scales are the result of placodes – small, thickened structures on the skin that develop at the embryonic level. But unlike most other species, including mice, where the placodes are random, a snake's placodes develop in a highly organised fashion, laying out the positioning of every single scale. Rather, the spatial organisation of these placodes follows a pattern in nature first explained by mathematician Alan Turing.

Scientists from Geneva wanted to know exactly how and why these near-perfect hexagonal patterns developed on the dorsal scales located on the snakes' backs and flanks, but not on the ventral scales that form as a single row on the animals' underbellies.

The researchers found that an embryo's ventral scales develop first and align with the position of somites, blocks of cells that determine the location of the vertebrae, ribs, muscles and dermis of the skin. Once the ventral scales are established, two separate 'waves' of placodes develop, travelling toward each other. The waves meet laterally, creating the tidy hexagonal patterns that are the hallmark of a snake's skin.

"To confirm our work, we used computer simulations and received similar results," said Athanasia Tzika, a postdoctoral fellow in the Department of Genetics and Evolution at the University of Geneva. "This is surprising because the pathway is essential for proper development of skin appendages in birds, reptiles and mammals." Tzika pointed to lizards with a mutated EDA gene, which were previously studied in her university's lab, as an example of a reptile that never developed scales. This led researchers to create the world's first genetically modified snakes. Using CRISPR-Cas9, which edits genes by severing the DNA and letting the natural DNA repair itself, Tzika and her team successfully created 'mutant' snakes that lacked dorsal-lateral (hexagonal) scales, but still had ventral scales.

She said that this proved that the scales aren't "self-organising" and occur "without a functional canonical EDA pathway." In total, the scientists created four corn snakes, all of which are currently two years of age and "are doing well," Tzika said. "The animals we produced are exactly the same as the naturally occurring snakes; we were able to reproduce the same phenotype." She said they plan to conduct another round of CRISPR edits on the genetically modified snakes in two years, once they reach sexual maturity, "to see if the mutation will transmit to the next generation."

Did you know?

Not all snake species lay eggs

© Getty / University of Geneva / MOLA

GLOBAL EYE

PLANET EARTH

WORLD'S DEEPEST CANYON IS HOME TO ASIA'S TALLEST TREE

WORDS **LYDIA SMITH**

A cypress tree in China is the tallest tree ever discovered in Asia. It is also believed to be the second-tallest tree in the world, standing at 102.3 metres tall. It was discovered in May by a Peking University research team at the Yarlung Zangbo Grand Canyon nature reserve in Bome County, in the Tibet Autonomous Region of China.

The species the cypress belongs to is unclear, although Chinese state media publications suggested it is either a Himalayan cypress (*Cupressus torulosa*) or a Tibetan cypress (*Cupressus gigantea*). In May 2022, the team found an 83-metre fir tree in southwest China, which they initially believed was the largest tree in China. Continuing their survey this year, the researchers used drones, lasers and radar equipment to map out the trees in the area and identify their heights from the ground.

After days of field surveys, the cypress was found and confirmed as the tallest tree in Asia. Using drones, a 3D laser scanner and lidar technology, which uses light beams to provide distance measurements, the team created a 3D model of the tree. Using this, they confirmed it was the tallest tree in Asia. The tree's supporting roots are not completely buried underground and it has a branching system that provides a habitat for some endangered plants and animals.

An aerial view showing the giant cypress measuring 102.3 metres

ANIMALS

Spider kills prey with gruesome tactic

WORDS **ETHAN FREEDMAN**

Fuzzy, long-legged spiders may attack their prey with an ingeniously gruesome tactic – by covering them in toxic digestive fluids. Unlike most other spiders, feather-legged lace weavers (*Uloborus plumipes*) don't have venom-producing glands or a way to inject their prey with toxins through their fangs. Instead, these spiders seem to produce neurotoxins in their gut, which may help explain their unusual hunting strategy of dousing their victims in fluids from their digestive system, researchers have discovered. "It really looks like there's something in these digestive fluids that kill the prey," which could be the toxins found in this study, said Giulia Zancolli, an evolutionary biologist at the University of Lausanne in Switzerland.

When most spiders trap an insect in their web, they inject it with venom from their fangs to paralyse it. They then cover each bite with digestive fluids to help break the insect down before consuming it. But spiders in the Uloboridae family, such as feather-legged lace weavers, wrap their victims in a copious amount of silk, before covering them in fluids and eating them. While scientists already knew about this unusual behaviour, they weren't exactly sure how the prey actually died.

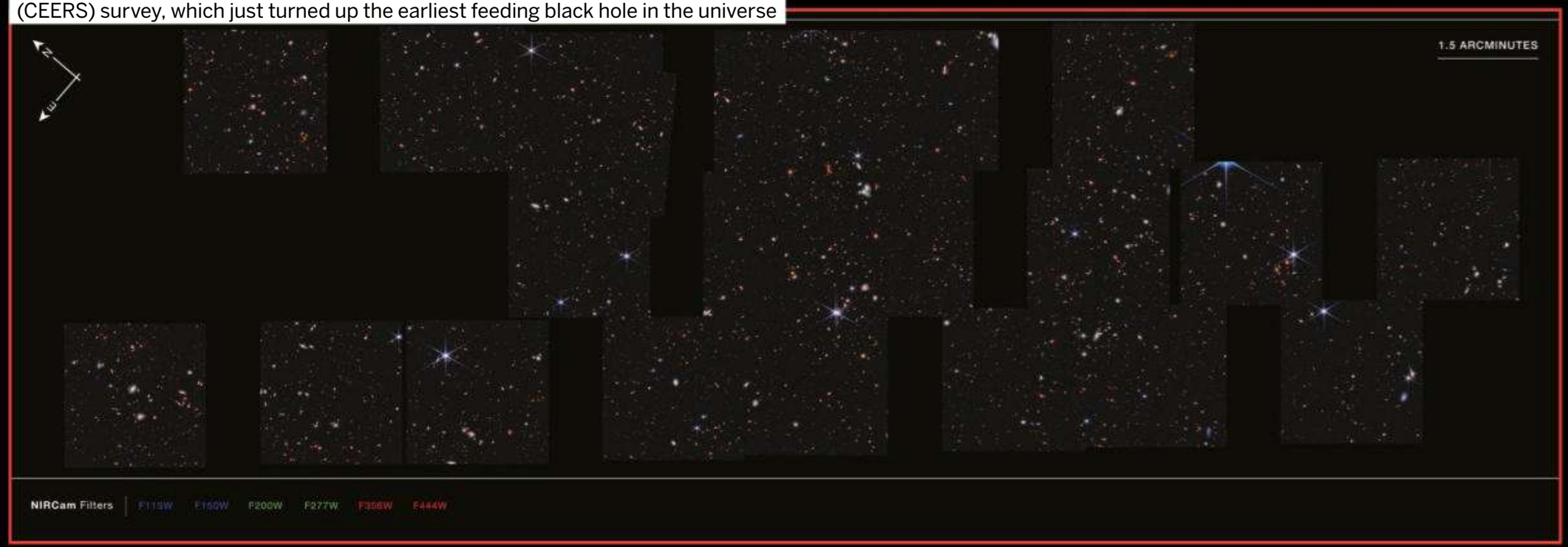
Did you know?

Some spiders eat their own webs in order to recycle the material

To investigate, Zancolli and her colleagues extracted RNA, a cousin to DNA, from different parts of feather-legged lace weavers. RNA can contain instructions for cells on how to make different materials, so by extracting RNA from different areas of the spiders' bodies, the researchers could see what kinds of compounds the animals were producing and where they were being produced. The researchers then looked at the structure of each of those compounds to determine whether they were likely to be toxic.

The team didn't find many potential toxins near the spiders' heads, nor did they find many in their silk. But they did find RNA for multiple potential toxins in the midgut gland – an organ that produces digestive fluids – indicating that the digestive fluid may be toxic. In addition, the team found no evidence of venom glands or a typical venom-delivery system through the fangs. The team didn't actually examine what was in the digestive fluid itself, but Zancolli noted that in another recent study, scientists did find toxins in an *Uloborus* digestive system. This discovery could show that while spiders in the Uloboridae family may not be able to inject venom through their fangs, they may still be using toxins, in a unique, vomity way.

Feather-legged lace weavers (*Uloborus plumipes*) appear to douse their prey in toxic digestive juices to immobilise them



A zoomed-in Webb image taken for the Cosmic Evolution Early Release Science (CEERS) survey, which just turned up the earliest feeding black hole in the universe

SPACE

Oldest active black hole in the universe discovered

WORDS **ROBERT LEA**

Astronomers using the James Webb Space Telescope have detected the most distant, actively feeding supermassive black hole ever observed. The black hole also happens to be one of the least massive seen in the early universe, measuring the equivalent of about 9 million suns, which is proving challenging to explain. Researchers observed the galaxy hosting this active supermassive black hole as part of the Cosmic Evolution Early Release Science (CEERS) Survey. Designated CEERS 1019, the galaxy is seen as it was when the 13.8 billion-year-old universe was just around 570 million years old.

The team, led by University of Texas at Austin astronomer Steven Finkelstein, also spotted two other black holes that existed 1 and 1.1 billion years after the Big Bang, as well as 11 galaxies that existed between 470 million and 675 million years into cosmic history. "Until now, research about objects in the early universe was largely theoretical," said Finkelstein. "With Webb, not only can we see black holes and galaxies at extreme distances, we can now start to accurately measure them. That's the tremendous power of this telescope."

The black hole at the heart of CEERS 1019 is around nine million solar masses. This may sound tremendously massive, but many supermassive black holes can grow to have billions of times the mass of our star. Yet, even at this relatively diminutive size, the existence of black holes of such masses in the early universe is still a puzzle for scientists. This is because the processes by which supermassive black holes grow, either by mergers between successively larger black holes or by greedily feasting on surrounding matter, should take longer than the 570 million years this black hole had to work with. This means that even black holes on a scale of that at the heart of the Milky Way, which has around 4.5 million times the mass of the Sun, should only be seen in the relatively close, and thus more recent, universe.

"Looking at this distant object with this telescope is a lot like looking at data from black holes that exist in galaxies near our own," said Rebecca Larson, a University of Texas at Austin doctoral student. Scientists have long suspected that such supermassive black holes existed in the early universe, but it is only since Webb opened its infrared eye to the cosmos in mid-2022 that definite proof has emerged. Light emissions reveal that black hole CEERS 1019 is actively feeding on matter around it.

Feeding black holes like this one are surrounded by swirls of infalling gas and dust known as accretion discs. Not only does the gravitational influence of the black hole heat this matter, causing the disc to glow brightly, but powerful magnetic fields channel matter to the poles of the black hole, where it is blasted out in twin jets moving at near light-speed, generating intensely bright light. Further observing the black hole's intense radiation could reveal how quickly its host galaxy is growing, and possibly shed insights on its mysterious past.

© Getty / Perking University, Xinhua, Jigme Dorje / NASA, ESA, CSA, Steve Finkelstein (UT Austin), Micaela Bagley (UT Austin), Rebecca Larson (UT Austin)

Dupuytren's contracture, often called 'Viking Disease', is a disorder in which fingers are bent or frozen

HEALTH

Mysterious 'Viking disease' linked to Neanderthal DNA

WORDS **DR. ALAKANANDA DASGUPTA**

Neanderthal genes may be one cause of the disorder nicknamed the 'Viking disease', in which fingers become frozen in a bent position. New research found gene variants that were inherited from Neanderthals that dramatically increase the odds of developing the condition, officially called Dupuytren's disease.

Dupuytren's disease is a hand disorder named after a French surgeon, in which the fingers, typically the ring and little fingers, become permanently locked in a bent position. The condition is common in Northern European countries where the Vikings settled, hence its nickname. It typically afflicts about 30 per cent of men over 60 years in northern Europe and seems to run in families. Treatment is mainly surgical, but recurrence is common. Although smoking, alcoholism, diabetes and anti-seizure medication can increase the odds of developing it, the exact cause has remained elusive.

The rarity of Dupuytren's disease among Africans led Dr Hugo Zeberg, an evolutionary geneticist at the Karolinska Institute in Stockholm, to wonder whether the genes tied to the disease came from Neanderthals, given that Africans have very limited Neanderthal ancestry. The researchers combined data from three large biobanks in the US, the UK and Finland comprising 7,871 cases and 645,880 controls in people of primarily European descent. They found 61 genetic variants tied to a higher risk of Dupuytren's disease. Next, they compared these gene variants with the previously sequenced Neanderthal genome. To their surprise, they discovered that of these 61 variants, three were of Neanderthal origin, two were very strongly linked to the disease. The Neanderthal gene most strongly linked to the disease, called EPDR1, sits on chromosome 7.

Did you know?

Vikings had good personal hygine

This isn't the first time that Neanderthal genes left behind in modern humans have been linked to disease. A 2014 study tied several present-day human diseases, such as diabetes, Crohn's disease, lupus and cirrhosis, to Neanderthal DNA remnants. But the link between Dupuytren's disease and these Neanderthal gene variants is especially strong. Two of the genetic mutations were the second- and third-most strongly associated with the odds of having the disease. "This is a very strong association," said Zeberg. "It's an interesting study that sheds new light on the genetic basis of Dupuytren's disease," said Serena Tucci, an anthropologist and evolutionary geneticist at Yale University.

People with roots outside Africa have about two per cent Neanderthal DNA in their genome. So statistically, by random chance, you would expect Neanderthal DNA to collectively account for around two per cent of the genetic risk of the disease. "But here we find that 8.4 per cent is explained by Neanderthal gene flow," much more than is expected by chance alone, Zeberg noted. Previous work on Dupuytren's implicated the EPDR1 gene; this gene encodes ependymin-related 1 protein, which plays a role in muscle contractility. The new research strengthens the case that mutated versions of the EPDR1 protein lead to Dupuytren's. The study has implications for future targeted therapy, Zeberg said. As next steps, Zeberg hopes to do more clinically oriented research on the disease.

Water pumped from aquifers between 1993 and 2010 caused sea levels to rise and the planet's axis to tilt eastward

PLANET EARTH

Human impact on Earth's tilt concerns scientists

WORDS **SASCHA PARE**

Humans pumped and displaced so much groundwater in just two decades that we shifted the tilt of Earth's axis, new research suggests. Earth's rotational pole, the point around which the planet rotates, shifts with changes in the distribution of mass across the globe, wobbling and wandering in a process called polar motion. While scientists knew that changes in water distribution resulting from climate change could contribute to polar motion, the impact of groundwater depletion was unknown.

Now, researchers estimate that by pumping 2,150 gigatonnes of water, almost enough water to fill Lake Victoria in Africa, and equivalent to the weight of 5.5 million Empire State Buildings, from underground layers of water-saturated rock known as aquifers, humans caused a pretty significant eastward shift of 80 centimetres in Earth's rotational pole between 1993 and 2010. That's because groundwater used for irrigation and other human activities eventually ends up in the ocean, which redistributes mass from where the water was taken to other parts of the globe.

"Earth's rotational pole actually changes a lot," said Ki-Weon Seo, a geophysicist at Seoul National University in South Korea. "Our study shows that among climate-related causes, the redistribution of groundwater has the largest impact on the drift of the rotational pole."

What's more, the extracted groundwater that ended up in the oceans may have boosted global sea level rise by around 6.24 millimetres. "Groundwater depletion is a significant contributor to sea level rise," the researchers wrote in the new study. Globally, roughly 70 per cent of the water pumped from the ground is used for irrigation, but only half of that trickles back down to replenish aquifers and other freshwater sources. The other half evaporates and ends up in the ocean through rainfall. To determine how much groundwater depletion and resulting sea level rise contributed to polar drift, geophysicists built a model of polar motion that accounted for shifts in water mass associated with thinning ice sheets, melting glaciers and water storage in reservoirs.

When they excluded groundwater redistribution from the model, the results did not match observed eastward polar drift and, instead, predicted a much more westward tilt. When they added the 2,150 gigatonnes of water from aquifers into the model, the results matched up with recorded observations of Earth's eastward drift. Other non-negligible changes in water and mass distribution may have played a role in polar motion between 1993 and 2010, including shifts in natural lake levels, mantle convection and earthquakes. However, these are difficult to quantify, and no global database currently exists. While polar shifts recorded in the last few decades are unlikely to affect the length of days or seasons, the finding illustrates just how much water humans have pumped from the ground.

SPACEFLIGHT

THE ORION SPACECRAFT GETS A HEAT SHIELD FOR ITS MOON MISSION

WORDS **JOSH DINNER**

NASA is making headway in its preparations for the Artemis II mission. Technicians at NASA's Kennedy Space Center (KSC) in Florida have attached the heat shield to the Artemis II Orion spacecraft. Orion and its four-person crew are scheduled to launch atop NASA's Space Launch System (SLS) rocket in 2024. The mission will carry them into deep space around the Moon, farther than any human has flown.

In November 2022, an uncrewed Orion capsule launched on Artemis I, a 25-day trip to lunar orbit and back. Artemis II will employ a free-return trajectory profile, which forgoes an orbital injection burn at the Moon and puts the spacecraft on a path back to Earth. Once Orion completes its lunar pass, the Artemis II crew will be on a course back to Earth.

As it returns, Orion will hit the atmosphere travelling more than 25,000 miles per hour. Temperatures on the exterior will get as high as 2,760 degrees Celsius. Orion's heat shield will absorb the majority of that energy, enabling the cabin to remain at comfortable temperatures. Teams completed the Artemis II heat shield installation on 25 June, inside the Neil Armstrong Operations and Checkout Building at KSC.

Installation of the heat shield for the Orion spacecraft was recently completed at NASA's Kennedy Space Center in Florida

© Getty / NASA;Cory Huston

WISH LIST

WILDLIFE WATCHING GADGETS

BIRDFY FEEDER

WWW.NETVUE.COM £194.68 / $249.99

Arguably one of the most high-tech bird feeders that you can buy, the Birdfy Feeder not only gives you a bird's eye view of your feathered visitors, but also uses AI to identify them. Unlike other bird feeders with cameras, Birdfy's accompanying app uses bird-recognition AI software to scout through more than 6,000 species to find the one that visited your feeder.

You also won't have to miss any of the action at the feeder, because Birdfy will notify your smartphone when you've got a new visitor and will store your bird history for 30 days using the Netvue cloud storage system. There's also the option to use an SD card for more storage and you can purchase an accompanying solar panel to keep your camera charged all the time.

SEEK THERMAL COMPACT

WWW.THERMAL.COM FROM £239.95 / $249

Turn your smartphone or tablet into a thermal imaging device thanks to the Seek Thermal Compact. The simple plug-in device can help its users spot hidden creatures in dense forests and spot nocturnal animals in the dead of night. Simply connect the sensor to your smartphone and, using the accompanying app, you'll see the world around you in a whole new thermal light.

The Seek Thermal sensor has a detection distance of around 304 metres and can register temperature fluctuations of between -40 degrees Celsius and 330 degrees Celsius. The sensor also comes with a waterproof case for all-weather use.

ECHO METER TOUCH 2

WWW.WILDLIFEACOUSTICS.COM £209 / $179

In the UK there are 18 different species of bat. The Echo Meter detector can capture their vocalisations and make an identification. Whether you're on an evening stroll or sitting in your back garden at night, this handy device lets you discover what bat species are nearby. Simply plug the device into your smartphone and the accompanying app will detect and record bat calls, which are at a much higher frequency than the human ear can detect. The app will analyse the ultrasonic sound of each bat and identify the species for. Currently, the Touch 2 can identify bat species found in North America, Europe, South Africa and the Neotropics.

SIMON KING WILDLIFE HIDE

WWW.SIMONKINGWILDLIFE.COM

£252 (APPROX. $326.30)

If you're looking to blend in with nature for a better view of the wildlife around you, a camouflaged hideaway is one way to watch undetected. The Wildlife Hide is a great example of an easy-to-assemble, spacious but also functional hideaway, good for wildlife photographers and bird watchers alike. The 1.42 square metre hide comes with two viewports on all four sides, perfect for concealing photography equipment. The exterior of the hide is covered in a leafy camouflage and comes with silent cord pulls on each zip toggle. The hide is also waterproof and made from breathable, lightweight material to reduce condensation within.

GARDEPRO E6 WILDLIFE CAMERA

WWW.GARDEPROSHOP.COM

£76 / $96.99

Keep an eye on what's walking through the wilderness using this WiFi-enabled trail camera by GardePro. This outdoor camera comes with a built-in WiFi module that connects to your smartphone within 13 metres, using the accompanying app to send you notifications when it detects nearby movement. The E6's integrated passive infrared sensors mean that as soon as an animal, such as a foraging deer or badger, passes the camera, it will automatically snap a picture with 0.5 seconds of detection. This camera comes with a 32-megapixel resolution and a 110-degree field of view, with the option to record high-definition video footage and sound for up to five minutes.

MS003 PORTABLE DIGITAL MICROSCOPE

WWW.SHOPAPEXEL.COM $149 (APPROX. £115)

Get up close and personal with the natural world using this portable digital microscope by Apexel. The microscope has a magnification range from 20x to 200x, perfect for observing the finer details of plant and insect specimens. The view of your specimen is shown on a bright LCD screen that can be tilted up to 75 degrees. The microscope also comes with a raisable platform and adjustable light source for an optical view. Also, the two-megapixel camera and infrared-reducing optical system let you take high-resolution images and video footage of your outdoor discoveries.

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HOW TO GROW MEAT IN A LAB
HOW POWER TOOLS WORK
WHAT IS AN AI CHATBOT?
HOW ARTIFICIAL INTELLIGENCE CAN CREATE ART, WRITE ESSAYS AND EVEN HAVE A HUMAN CONVERSATION WITH YOU
WHAT IS A ZOETROPE?
HOW E-INK WORKS
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SPECIAL

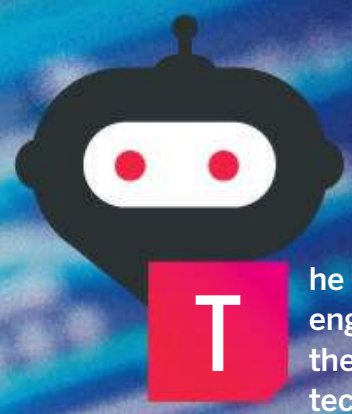
RISE AI

DID YOU KNOW? The first AI was a computer program that could play checkers

OF THE CHATBOTS

How breakthroughs in artificial intelligence are making everyday chatbots smarter than ever

WORDS MARK SMITH



The printing press, the steam engine, the electric light bulb, the internet itself... all were technological breakthroughs that redefined how we live and work. Every so often, technology takes a massive leap forward that goes so fast and so far, society struggles to keep pace with the speed of change it brings. Recent developments in chatbots like ChatGPT and Google Bard have ushered in one of those new eras. So much so that even some of the brightest minds behind them aren't quite sure what they're yet capable of. Should we be worried? Or is this all simply another breakthrough that one day we'll look back on and wonder how we ever lived any other way?

A chatbot is a piece of software that responds to us the way a human would when we talk to it, either by typing or talking. Chatbots can respond to our questions, help organise our days, play our favourite music, write poetry, design images, control our smart homes and even offer advice. Think of them like a friendly face covering all the cold and digitised bits of code that make up the databases and servers that form the technology our modern world is built on. For instance, a chatbot might be a customer service agent at your mobile phone provider. Instead of having to go trawling through lots of different databases and spreadsheets to find out what you need to know – such as how much last month's phone bill was – you just ask the chatbot.

The chatbot analyses your question and puts it into context using artificial intelligence (AI) to figure out what you want. The chatbot then does all that sifting for you. It goes through all the back office systems at the

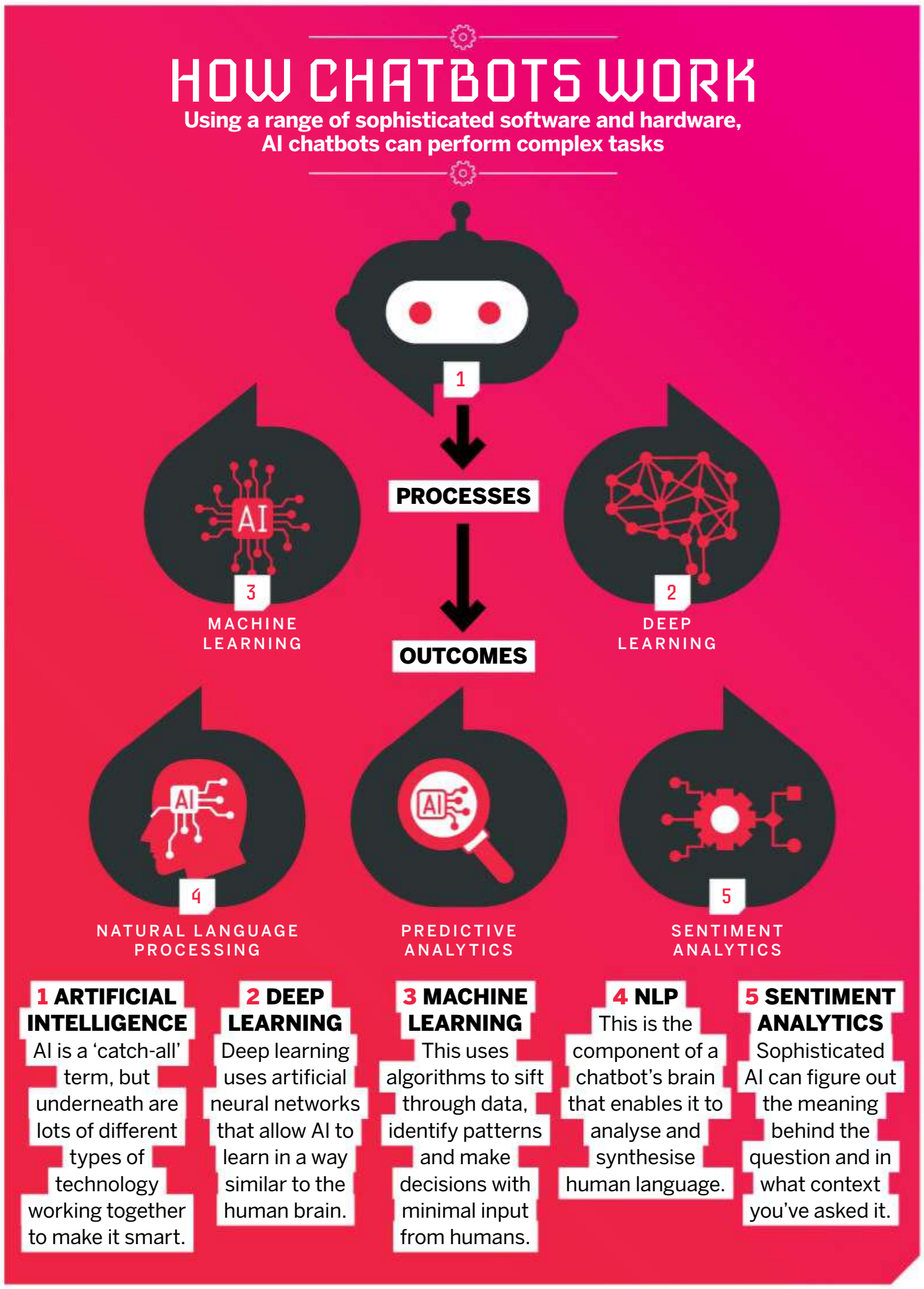
© Getty

mobile phone company and presents you with a simple answer – just as though you were talking to a person, only much faster. What's changed is how sophisticated these chatbots are becoming. Sure, asking one a simple question about your bill will bring you a simple answer. But what if you asked it to design a new type of car, write an entire novel for you or even sit a law exam for you while you go to the coffee shop instead? Now they can do all of these things too, and much more.

The integration of breakthroughs in AI natural language processing (NLP) and machine learning (ML) have seen huge leaps forward in the last year alone. These advances are making people question just how far chatbots could advance, what kind of roles they could perform in wider society and how that could impact us all. You've probably heard of Alan Turing, of Bletchley Park fame. A war hero and one of the forefathers of modern computer science, he designed early computers to crack German World War II codes that helped the Allies win the war. And it was Turing that laid the groundwork for how we'd come to understand modern chatbots. Back in the 1950s, he was wondering if computers would ever be able to think, coming up with something called the 'Turing test'. This was a way of testing a computer's intelligence by seeing if a human could tell the difference between its responses and those of another human. This set in motion a new branch of computer science based around machines that could mimic the responses of humans.

The first real example of one doing so was in 1966 with ELIZA. Developed by Massachusetts Institute of Technology scientist Joseph Weizenbaum, it was designed to simulate the responses of a psychotherapist. When a user typed something in, ELIZA would spot certain keywords and type back with preprogrammed responses. Skip forward a few decades and the internet was born. Companies saw the opportunity to develop modern chatbots that would do things like answer customer queries.

In recent years we've seen big companies develop chatbots. Apple introduced Siri, a


HOW CHATBOTS WORK
Using a range of sophisticated software and hardware, AI chatbots can perform complex tasks
1
PROCESSES
AI
3
MACHINE LEARNING
2
DEEP LEARNING
OUTCOMES
AI
4
NATURAL LANGUAGE PROCESSING
AI
PREDICTIVE ANALYTICS
5
SENTIMENT ANALYTICS
1 ARTIFICIAL INTELLIGENCE
AI is a 'catch-all' term, but underneath are lots of different types of technology working together to make it smart.
2 DEEP LEARNING
Deep learning uses artificial neural networks that allow AI to learn in a way similar to the human brain.
3 MACHINE LEARNING
This uses algorithms to sift through data, identify patterns and make decisions with minimal input from humans.
4 NLP
This is the component of a chatbot's brain that enables it to analyse and synthesise human language.
5 SENTIMENT ANALYTICS
Sophisticated AI can figure out the meaning behind the question and in what context you've asked it.

GETTING SMARTER

1950

Alan Turing developed 'the Turing test' to see if humans could distinguish between machine and human responses.

1966

ELIZA, a program designed by MIT professor Joseph Weizenbaum, used pattern matching to have therapeutic discussions with a human.

1972

PARRY was built by American psychiatrist Kenneth Colby and was designed to imitate a patient with schizophrenia.

1988

British developer Rollo Carpenter created Jabberwacky, aimed to simulate human conversation in an entertaining way.

1995

A.L.I.C.E. (Artificial Linguistic Internet Computer Entity) was developed by Richard Wallace. It simulated chatting with a real person over the internet.

2001

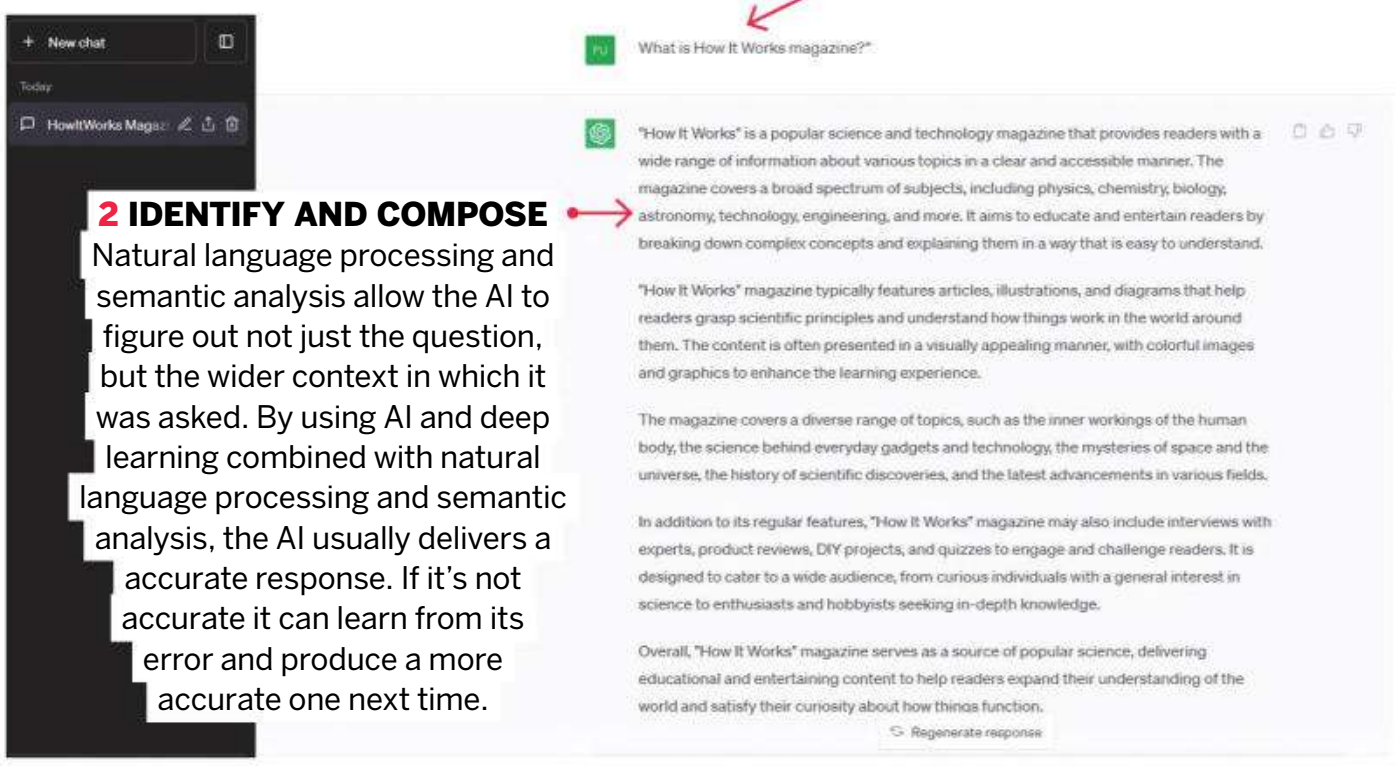
Widely regarded as a precursor to Siri, SmarterChild was available in AIM and MSN Messenger and could provide quick data access and have chats with users.

DID YOU KNOW? A robot built in the late 1990s called Kismet can recognise emotions

FROM QUESTION TO ANSWER

How do we get from input to output with an AI chatbot?

1 INSTRUCTING AND ANALYSIS
A user asks the chatbot to do something, either via text input or through speaking to it. The chatbot combines tech like machine and deep learning to understand what the user request means.


New chat
Today
HowItWorks Maga
What is How It Works magazine?"
"How It Works" is a popular science and technology magazine that provides readers with a wide range of information about various topics in a clear and accessible manner. The magazine covers a broad spectrum of subjects, including physics, chemistry, biology, astronomy, technology, engineering, and more. It aims to educate and entertain readers by breaking down complex concepts and explaining them in a way that is easy to understand.
"How It Works" magazine typically features articles, illustrations, and diagrams that help readers grasp scientific principles and understand how things work in the world around them. The content is often presented in a visually appealing manner, with colorful images and graphics to enhance the learning experience.
The magazine covers a diverse range of topics, such as the inner workings of the human body, the science behind everyday gadgets and technology, the mysteries of space and the universe, the history of scientific discoveries, and the latest advancements in various fields.
In addition to its regular features, "How It Works" magazine may also include interviews with experts, product reviews, DIY projects, and quizzes to engage and challenge readers. It is designed to cater to a wide audience, from curious individuals with a general interest in science to enthusiasts and hobbyists seeking in-depth knowledge.
Overall, "How It Works" magazine serves as a source of popular science, delivering educational and entertaining content to help readers expand their understanding of the world and satisfy their curiosity about how things function.
Regenerate response

2 IDENTIFY AND COMPOSE
Natural language processing and semantic analysis allow the AI to figure out not just the question, but the wider context in which it was asked. By using AI and deep learning combined with natural language processing and semantic analysis, the AI usually delivers a accurate response. If it's not accurate it can learn from its error and produce a more accurate one next time.

voice-activated virtual assistant, for the iPhone, while Google developed Google Assistant, a conversational AI assistant. They could answer questions, organise your day, play music and help you find your way around an unfamiliar city. Many of us now couldn't do without them.

But chatbots have always been limited in the accuracy of what they could do. They're not human and couldn't understand the context and meaning behind a question. Nor could they be especially creative. But a new generation of chatbots has changed all that. ChatGPT, which has been designed by technology startup OpenAI, is one such modern chatbot. Launched November 2022, within just two months it had reached more than 100 million active users and has become the fastest growing internet service ever.

Did you know?
There will soon be more AI assistants than people

How does it work? The clue is in the name. GPT stands for generative pre-trained transformer. Generative means that it learns from existing data to generate new content. Pre-trained means it has been input with lots of data from different sources, like grammar, facts, figures, language patterns and more, and lots of other facts from the internet. The 'transformer' aspect relates to something called transformer-based architecture, which enables it to process lots of data.

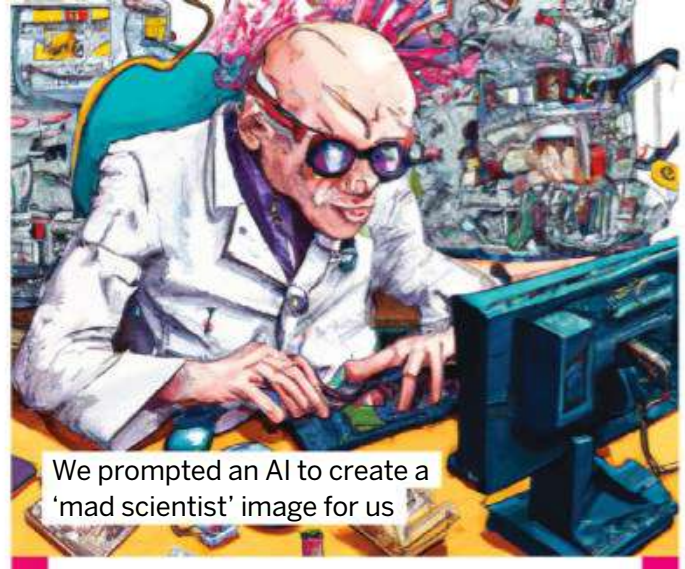
The bottom line is that ChatGPT can respond with a level of accuracy and even creativity that's never been seen before. It can write essays in seconds, create computer code, answer exam questions, compose music lyrics, create job applications, figure out complex scientific questions and provide advice, among a lot of other stuff. Most

2010
Apple created Siri for iOS. It was an intelligent personal assistant that used natural language. It helped launch a new breed of AI chatbots.

2012
Google Now was launched this year. It could answer questions and perform actions in response to user requests. It was replaced by Google Assistant in 2017.

2014
Cortana was first demonstrated at a developer conference and became directly integrated into Windows phones and Windows 10 PCs. Amazon's Alexa was launched the same year.

2022
OpenAI unveiled ChatGPT. It was designed to generate human-like text in response to input from users.



We prompted an AI to create a 'mad scientist' image for us

CREATING AN AI CHATBOT

What was it like to give birth to a groundbreaking new AI? Andrew Mayne, science communicator at OpenAI, tells us

What did it feel like when you realised what you'd achieved with ChatGPT?
I was brought on in early 2020 to play with GPT-3. I was blown away by how much more capable it was than GPT-2. Every day was something special. I remember playing around with the 'explain this to a ten-year-old' prompt and thinking about the kind of impact this could have on making sense of all the information we're flooded with. I'd create prompts and have long conversations. I kept thinking, if this is where we are now, what will it be like in five years? Just seeing how much things have advanced amazes me.

What do you say to people who are afraid of AI?
There's no doubt that AI is going to have a huge impact, and not all of it will be positive. I think the best approach is for people to learn more about the current state of AI, what it can do, its limitations and how it's going to impact things. We're in short supply of educators, medical specialists and other forms of expertise. AI has the potential to give people around the world the things we take for granted.

What do the next five years hold?
As more people learn how to use these tools and they become more capable, we're going to see them everywhere. Just like how an internet search became the normal way to interact with anything online, I think ChatGPT and systems like it will be just as indispensable.

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5 JOBS THAT AI COULD REPLACE

1 TECHNOLOGY
Workers like coders and computer programmers could have their jobs replaced because AI like ChatGPT can produce code faster than humans and with increasing accuracy.

2 WRITERS AND JOURNALISTS
ChatGPT is so good at writing that it can adapt to different styles, so writers and journalists could soon find themselves replaced.

3 ADMINISTRATION STAFF
There's a whole host of back-office work that AI could do, from scheduling appointments, making reservations, generating documents and transcribing meetings. This could replace admin staff and assistants in a whole host of industries.

4 TEACHERS
ChatGPT can answer a range of questions and explain them to people while adapting answers to their age and abilities. It's an ideal set of skills for an artificial teacher.

5 DESIGNERS
AI is becoming increasingly good at creating still images and videos. You can ask a chatbot to create things like 'a picture of Mickey Mouse in the style of Rembrandt' and it can do a pretty good job.

Did you know?
Human-robot marriage could be legal by 2050

of these tasks are virtually indistinguishable from how humans would do them, or in many cases better and quicker than we can.

Not all chatbots work in quite the same way, and there's lots of different methods being used to make them smarter and easier for people to interact with. Generative chatbots like ChatGPT have access to lots of text data and information drawn from different sources, including the internet as it looked in 2021. It then uses AI to figure out what you're asking it and then gathers the information together for you. Multimodal chatbots combine text with other types of media, like videos and images. They're used in e-commerce and can answer customer questions about things like pictures of products. Conversational chatbots use AI to try and figure out what you're saying in the context of how you're saying it. This enables them to provide personalised responses to your questions and are all about sounding natural and human.

Should we be afraid of chatbots? OpenAI boss Sam Altman, the man behind ChatGPT, has already spoken of his fears about how the technology could be misused, telling the US Senate: "My worst fear is that we, the field, the technology, the industry, cause significant harm to the world. If this technology goes wrong it can go quite wrong. We want to work with the government to stop that happening." There are plenty of scare stories out there, based on films like *2001: A Space Odyssey* and *The Terminator*, where artificial intelligence goes a bit crazy and starts doing some pretty bad stuff. But that's not the kind of thing people in the know are really worried about. What they're really worried about are things like the creation of disinformation. In this case, an AI chatbot could be used to create and spread

Sam Altman, chief executive officer of OpenAI, has raised concerns about the possible misuse of the company's technology

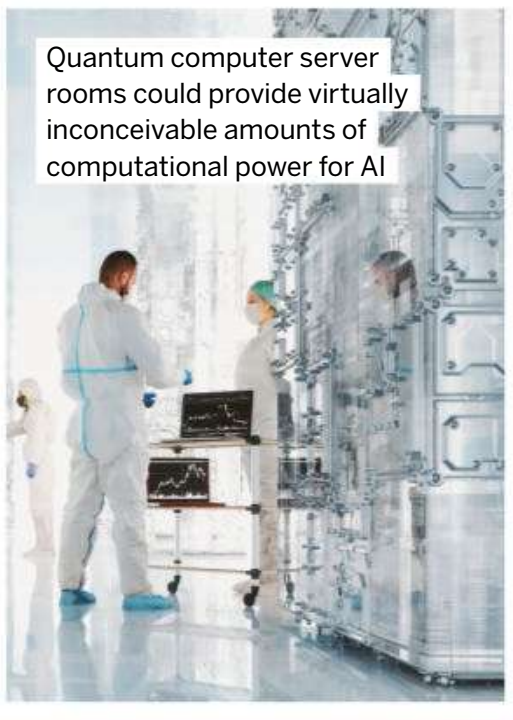
fake news that's very believable. Or it could generate realistic emails claiming to be from a friend or loved one asking for help or money. There are also concerns over how much of our personal and sensitive information chatbots can collect.

Another thing some people are worried about is the impact on jobs. Just as steam power enabled a new era of industrial production and travel around the world, it also put a lot of people out of work. The same is almost certainly going to happen with AI. They could in theory replace journalists and writers, lawyers, administration staff and designers – people whose jobs have never been under threat before. There could come a time where they're even teaching kids instead of teachers. One thing is clear, we're living in an era where breakthroughs are making chatbots smarter than ever, and the rate of change isn't going to slow down anytime soon.

"It's unlikely that an AI could ever be creative"

WHEN AI MEETS QUANTUM COMPUTING

What will happen when we combine two trailblazing pieces of future technology? Quantum computing harnesses the peculiarities of how physics acts at the subatomic level, where the rules are very different to the rest of nature. It means they could solve problems in an instant that a traditional computer could take hundreds of years to figure out. Traditional computing – even AI – has to perform tasks in sequence. It tries one door, and if it doesn't open it tries another one. A quantum computer could try all the doors at the same time. This all cuts down on time, processing speeds and inefficiency. In theory, a quantum computer AI could have huge computational power compared to what we have right now.



Quantum computer server rooms could provide virtually inconceivable amounts of computational power for AI

DID YOU KNOW? In 2013 AI had the same intelligence as a four-year-old. By 2029 it will have the same intelligence level as adult humans

HARDWARE FOR AI

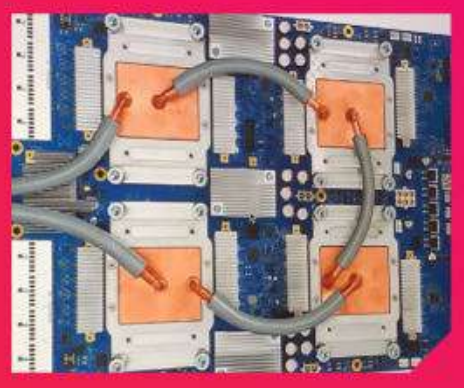
Artificial intelligence makes use of a range of sophisticated modern hardware

GRAPHICS PROCESSING UNITS

A GPU (Graphics Processing Unit) is a specialised processor with dedicated memory required for rendering graphics. But because AI algorithms rely on processors that can perform parallel computations, they're also used for AI.

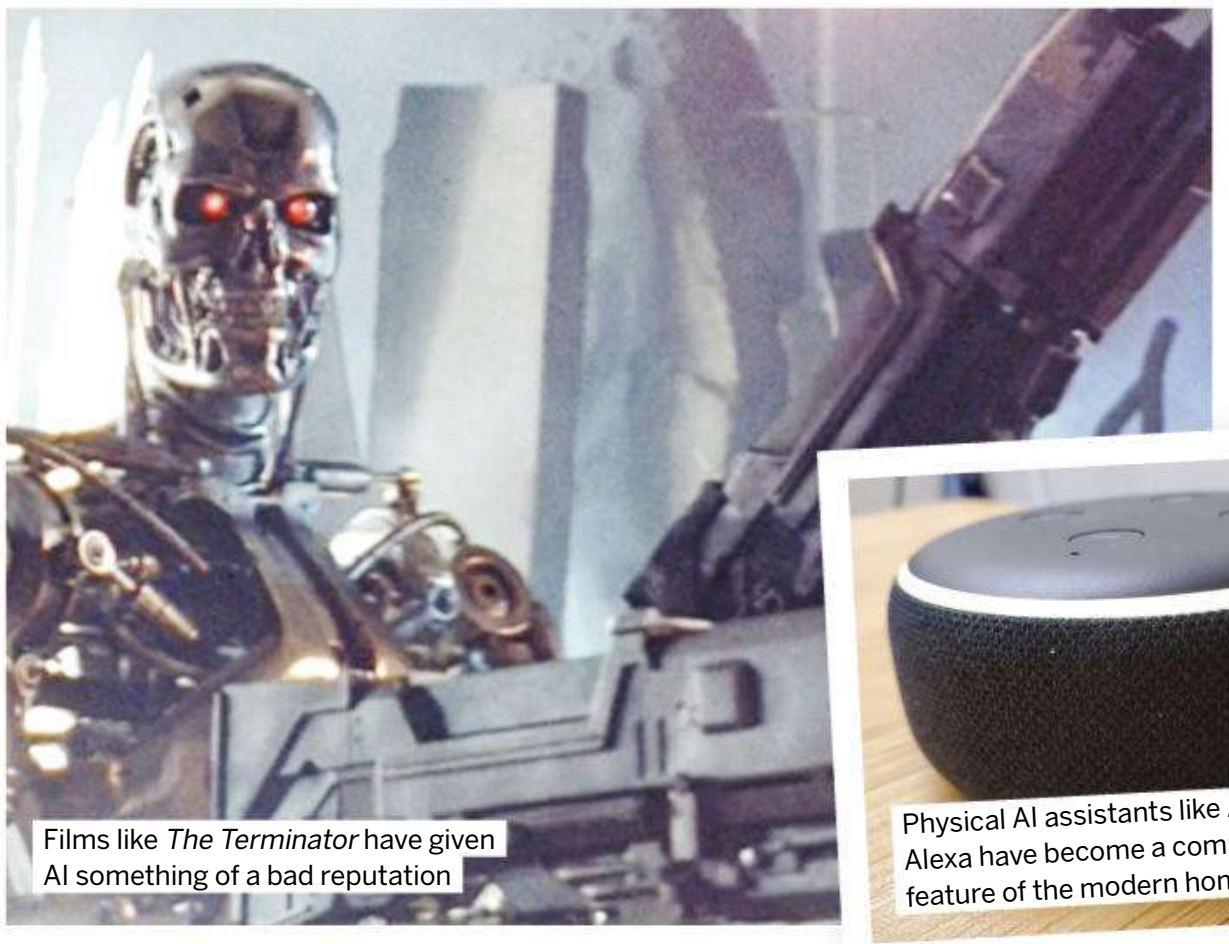
TENSOR PROCESSING UNITS

TPUs were designed by Google for all of its machine learning-powered services, including those found in its Pixel smartphone line. They handle tasks such as speech recognition, live translation and image processing.



NEUROMORPHIC HARDWARE

At the true cutting edge, this emulates the human nervous system with a neural network infrastructure. The network comprises interconnected processors, referred to as neurons. It will be one of the cornerstone technologies for the next generation of AI.



Films like *The Terminator* have given AI something of a bad reputation

Physical AI assistants like Amazon's Alexa have become a common feature of the modern home

COULD AI EVER BE TRULY CONSCIOUS?

Tom McClelland is a lecturer in the department of history and philosophy of science at Cambridge University. He ponders the deeper questions about AI

What's the difference between how AI chatbots and humans learn?

There are big differences between how brains and artificial networks update themselves. Machine learning works through a massive process of trial and error. It tries out different neural weightings more or less at random. If it performs better on a task, it retains those weightings, and if it doesn't it tries something else. Learning in the human brain works more efficiently. When I learn that black big cats are panthers, not tigers, I can understand where I've gone wrong and the required shift in connections can happen straight away. But the artificial network has to try out loads of different weightings until it stumbles across the one that works.

Will an AI ever be conscious?

Without understanding what makes us conscious, we can't assess the prospects of artificial consciousness. For instance, are we conscious because of our biological hardware or because of the information processes that are running on that hardware? If consciousness is bound to biology then the prospects of artificial consciousness are poor. But if consciousness arises whenever the right kind of information process occurs then there's an open possibility that AI could achieve consciousness.

Where do things like creativity and inspiration factor in with AI?

If you think of creativity as the ability to make something entirely original without being influenced by existing work, then it's unlikely that an AI could ever be creative. AI has to be given instructions and be given data, and it can never transcend these things to create something out of nothing. But if we adopt this really high standard for what counts as creativity, then humans wouldn't qualify as creative either. Even the most original artist doesn't create something out of nothing – they're heavily influenced by what they've been exposed to. Picasso, for instance, created very distinctive works of art, but he was shaped by a whole host of existing artworks.

© Getty / Tom McClelland / Zinskauf - Wikipedia

SPECIAL

CHATBOT AI BY NUMBERS

97 MILLION

Nearly 100 million new jobs could be created by AI

ONE MILLION

Number of users ChatGPT had just five days after being released

175 BILLION

Number of machine-learning parameters ChatGPT has

400 MILLION

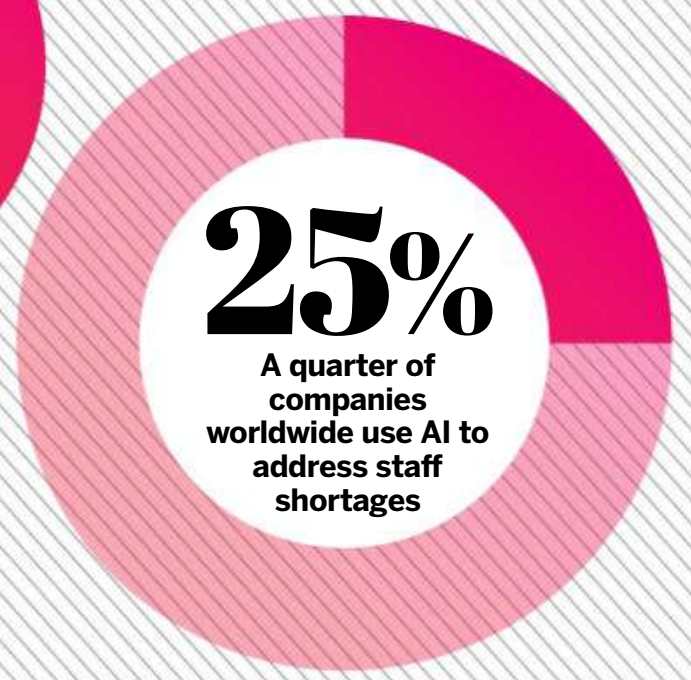
Number of workers who could be displaced by AI in the future

AI CAN ANALYSE IMAGES TO DIAGNOSE EARLY DISEASE IN PATIENTS

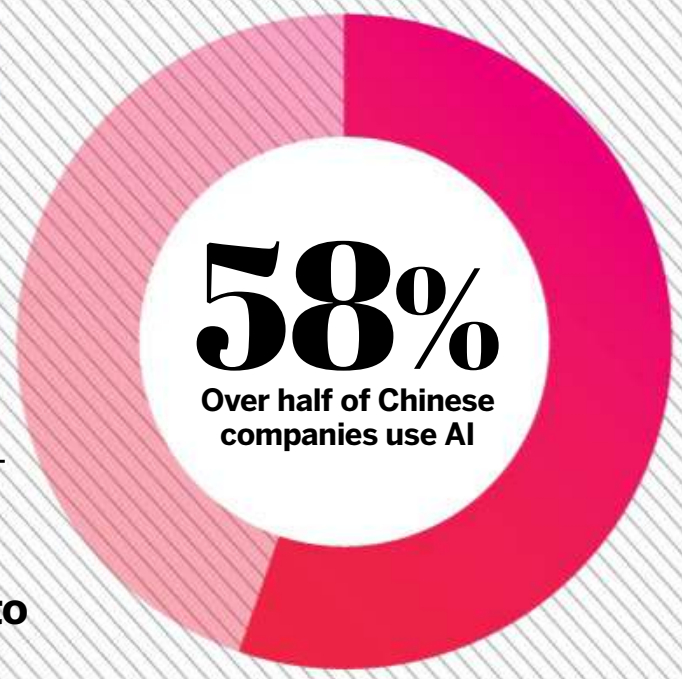
SELF-DRIVING CARS WILL USE AI IN THE FUTURE TO NAVIGATE AROUND OBSTACLES ON ROADS

$200 MILLION

Amount ChatGPT is forecasted to generate in 2023



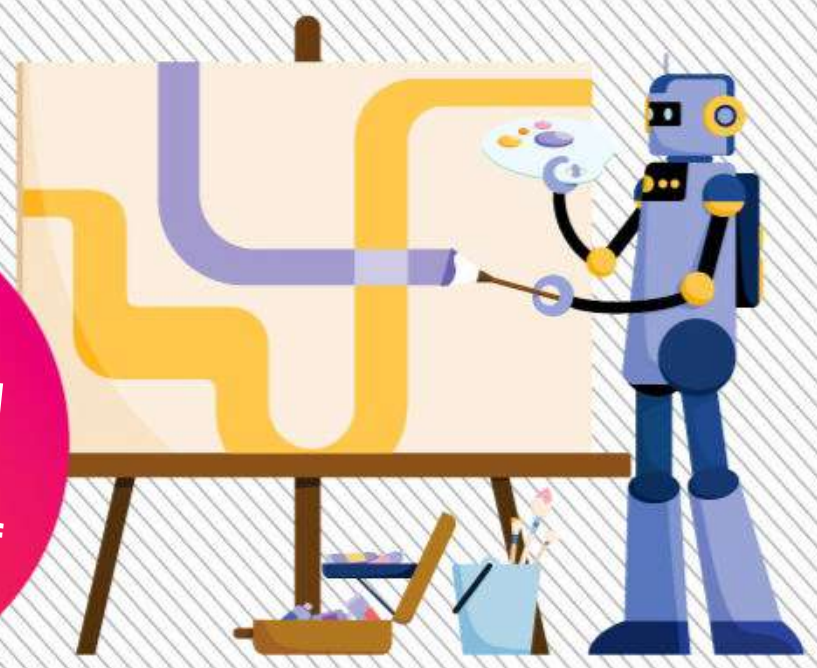
A quarter of companies worldwide use AI to address staff shortages



Over half of Chinese companies use AI

DID YOU KNOW? Assistants like Siri and Alexa are female because studies show people prefer the sound of a female voice

ARTIFICIAL INTELLIGENCE CAN CREATE NEW ART BY RECOGNISING PATTERNS OF EXISTING ARTISTS



77%

Most people are worried about AI causing job losses

$29 BILLION

ChatGPT is worth nearly a quarter of tech giant Intel

ChatGPT's training dataset contains over half a terabyte of text

97%

Almost all business owners believe ChatGPT will help them

570 GIGABYTES

AI CAN HELP PREDICT NATURAL DISASTERS BY ANALYSING MASSES OF DATA

50%

Half of mobile phone users use voice search on a daily basis

65%

Many consumers say they'll still trust companies that use AI

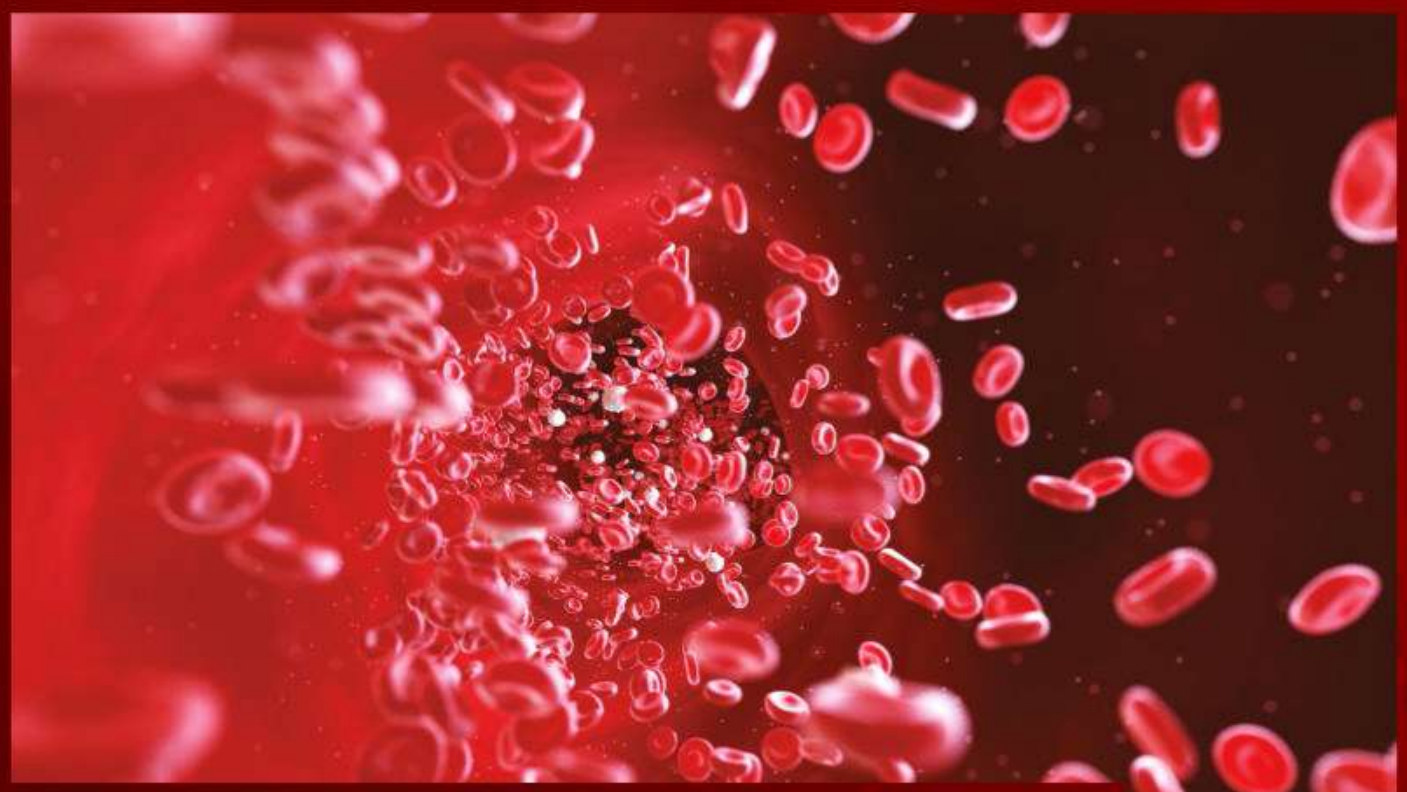
100 MILLION

ChatGPT has amassed a huge number of users in a short time

75%

Percentage of consumers who are worried about AI causing more misinformation

© Getty



HOW BLOOD TRANSFUSIONS WORK

Our bodies need blood to deliver oxygen and nutrients and remove waste. How do we receive more when we run dangerously low?

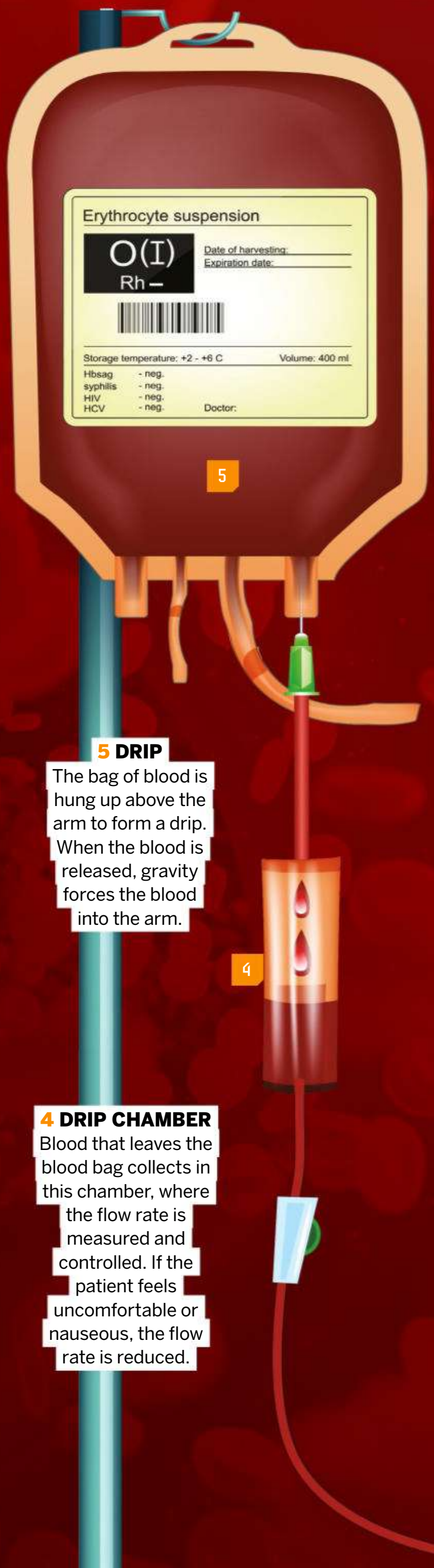
WORDS **AILSA HARVEY**

When a person loses blood due to injury or illness, preventing the body from functioning effectively, blood from another person may be needed. This is carried out through a blood transfusion. Transfusions rely on millions of blood donations around the world, sorted into blood types that match a patient's specific blood group to reduce the chance of their body rejecting it.

Blood donors give around 470 millilitres of blood per donation – about eight per cent of the average adult's blood volume – which takes between five and ten minutes. This is tested to make sure it's categorised into the right blood type and has no trace of disease. Because men generally have more iron in the blood than women, they can donate blood every 12 weeks, while women need to wait 16 weeks between donations. Not all blood transfusions require the blood of a separate individual. Autologous, or self-donation transfusions take place when a patient is donating blood for themselves in the future. This is usually for a preplanned surgery where the blood loss is predicted to be 20 per cent or more. Some examples of such operations include organ transplants, joint replacements and heart surgery.

Did you know?

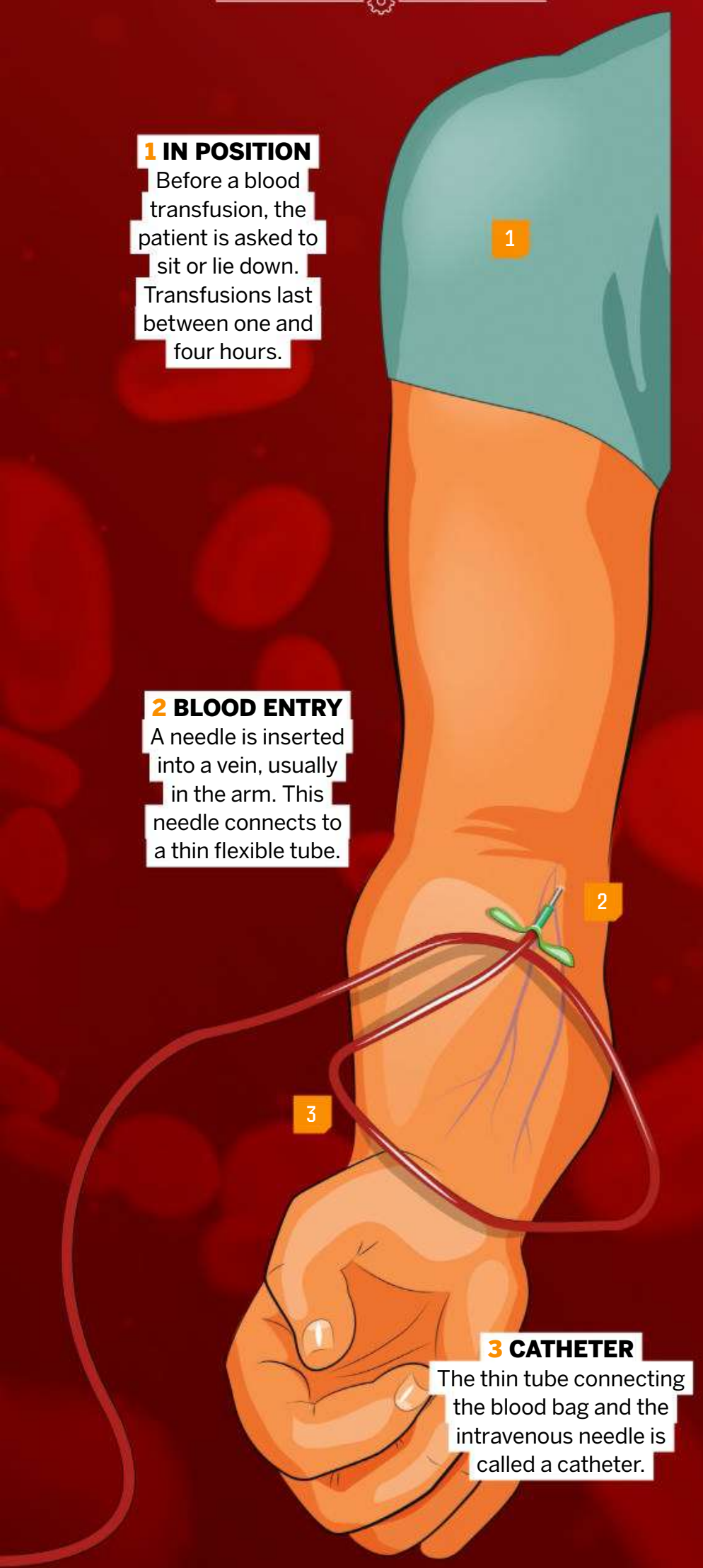
Blood type O is in the highest demand for transfusions


Erythrocyte suspension
O(I)
Rh –
Date of harvesting:
Expiration date:
Storage temperature: +2 - +6 C
Volume: 400 ml
Hbsag - neg.
syphilis - neg.
HIV - neg.
HCV - neg.
Doctor:
5
5 DRIP
The bag of blood is hung up above the arm to form a drip. When the blood is released, gravity forces the blood into the arm.
4
4 DRIP CHAMBER
Blood that leaves the blood bag collects in this chamber, where the flow rate is measured and controlled. If the patient feels uncomfortable or nauseous, the flow rate is reduced.

DID YOU KNOW? Someone in the US needs a blood transfusion every two seconds

RECEIVING BLOOD

How does the process of a blood transfusion work?



1 IN POSITION
Before a blood transfusion, the patient is asked to sit or lie down. Transfusions last between one and four hours.

2 BLOOD ENTRY
A needle is inserted into a vein, usually in the arm. This needle connects to a thin flexible tube.

3 CATHETER
The thin tube connecting the blood bag and the intravenous needle is called a catheter.

TYPES OF TRANSFUSIONS

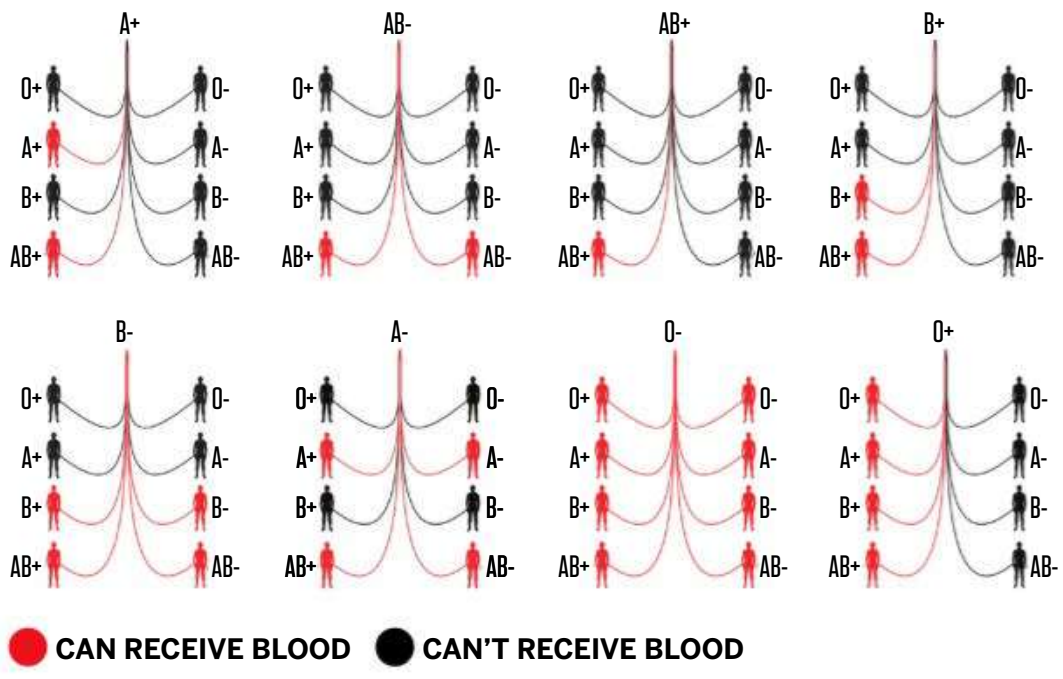
Blood transfusions are usually given because a specific component in the blood needs to be boosted in quantity. The main types of blood transfusions are red blood cells, platelets, plasma and whole blood. Red blood cells are the most common blood cell and hold the main role of delivering oxygen around the body. When a patient experiences significant blood loss due to injury or suffers from anaemia – a condition that causes the body to have a lower red blood cell count – a red blood cell transfusion takes place. Some anaemic patients require this procedure every few months.

Platelets are large cells in the blood that clump together when tissue bleeds. This forms a clot to prevent significant blood loss. Patients with low platelet counts, such as chemotherapy patients who have experienced damage to bone marrow, where platelets are made, are most likely to receive this type of transfusion. Meanwhile, plasma transfusions involve inserting the liquid component of blood into patients with severe burns or liver failure. This keeps blood pressure stable in burn patients, reducing shock, and replenishes plasma proteins in those with liver failure, as this is the organ they're produced in. Whole blood transfusions are reserved for the most severe blood loss incidents, where all blood components need replenishing.

A centrifuge machine spins blood donation samples to separate red blood cells, platelets and plasma

WHAT BLOOD GROUPS CAN YOU RECEIVE?

Every cell in the body is covered in molecules called antigens, which work like identification tags to tell the immune system which cells belong to the body and which are invaders. When the body encounters foreign antigens, an immune response is triggered to eliminate these potentially harmful cells. Your blood is no different, with each person's red blood cells having a specific antigen type based on their genes. These can be categorised into four main blood types: A, B, AB and O. The next factor to consider in blood transfusions is the presence of the protein Rh on the blood cells. If this protein is present, the person has a positive blood type, while a negative blood type lacks this protein. It's more common to have this protein, but lacking it doesn't lead to illness. As each of the four blood types can be either positive or negative, there's a total of eight general categories.



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A nugget made from lab-grown chicken meat, made in Singapore in 2020

LAB-GROWN
BEEF
CULTURED
MEAT
Meat produced by in vitro cell culture of animal cells.
| CRUELITY FREE | SAFE | HEALTHY | ENVIRONMENTALLY FRIENDLY |
Eat meat with a clear conscience.
LAB-MEAT-6933
NET WT. 17OZ (482g)

LAB-GROWN MEAT EXPLAINED

Would you eat chicken or beef that's been grown in a laboratory?

WORDS **SCOTT DUTFIELD**

Could lab-grown meat be the compromise that settles the conflict between meat-eaters and vegetarians? For more than 2.5 million years humans have feasted on the flesh of other animals. During this time, the world's agriculture industry has boomed, with 26 per cent of Earth's ice-free land dedicated to livestock, which comes at a cost to the environment. On average, the livestock industry is responsible for around 18 per cent of global greenhouse gas emissions.

To help minimise environmental impact and reduce the space needed to house livestock, scientists have started growing food far from the fields, inside their laboratories. In the same way that farmers grow and nurture livestock from calves and chicks, scientists care for a collection of tiny cells that have been extracted from the genuine article without the need to slaughter a living animal.

A small sample of stem cells, typically taken from animal muscle via a small biopsy under local anaesthetic, is collected and placed in a culture to grow. Stem cells act like the understudies of the body's other cells: when stimulated, stem cells can develop into specialised cell types, such as muscle and fat cells. To grow meat, which is essentially a collection of fat and muscle cells, scientists expose the extracted stem cells to amino acids and carbohydrates that trigger their ability to change. The changing stem cells are left to grow and multiply until a heap of muscle fibres has developed and the new meat is plentiful enough to use in meat products, such as burgers.

Did you know?

1.5 billion cows are eaten globally each year

So far, only a handful of animal species have had their cells turned into this novel form of meat, including cows, chickens and pigs. However, some companies plan to expand into more exotic meats, such as kangaroo, alligator and ostrich. Currently, lab-grown meat isn't widely available. The first country to allow the sale of cultured meat was Singapore in 2020. In 2023, American companies such as the San Francisco start-up Upside Foods were given the green light to sell their cultured meat products in the US.

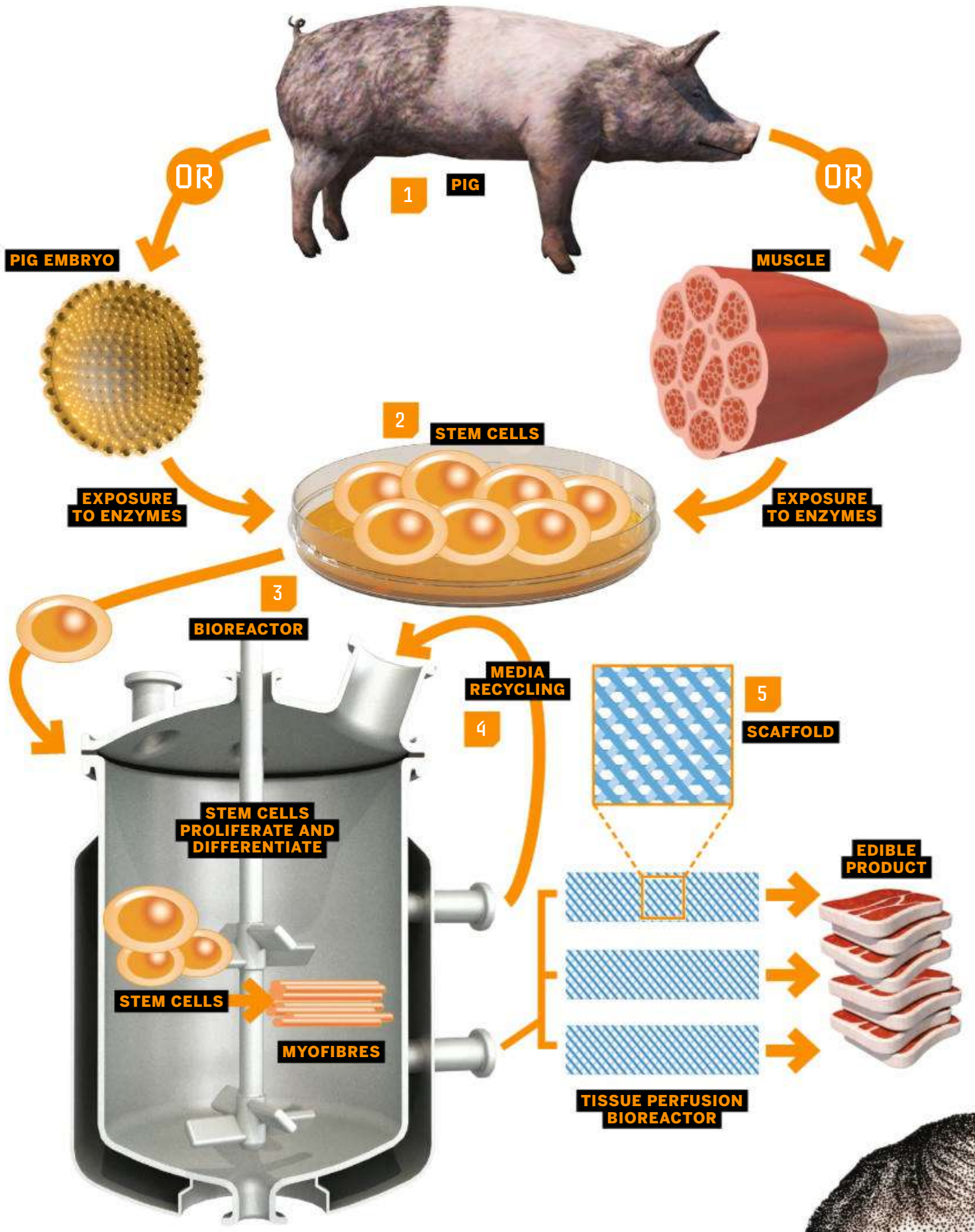
"Only a handful of species have had their cells turned into this novel form of meat"

MAMMOTH MEATBALLS

So far, lab-grown meat has been limited to cows, chickens and pigs. But what if you could feast on the meat of animals long extinct, like the mighty mammoth? An Australian company called Vow has done just that. Combining the DNA of the extinct woolly mammoth (*Mammuthus primigenius*) and its closest living relative, the African elephant (*Loxodonta*), Vow served up the first mammoth meatball in March 2023. Although the meatball looked tasty enough to eat, it's yet to pass anyone's lips. Fears over the safety of the meat and the possible negative immune response of the human body mean that the taste of mammoth meat remains a mystery.

The mammoth is back, but in meatball form

DID YOU KNOW? A fully grown cow can release up to 500 litres of methane into the atmosphere each day



MAKING MEAT

The process that puts artificially grown meat on your plate

1 EXTRACTION
A collection of stem cells is taken from an animal's muscles, or in some cases from a fertilised embryo.

2 BEST OF THE BUNCH
Of the extracted cells, these are the cells that are best at producing high-quality meat.

3 GROWTH SPURT
The cells are placed into a bioreactor, where they are fed nutrients and water so that they start to grow and multiply.

4 TRANSFORMATION
While in the bioreactor, stem cells differentiate (transform into different specialised cells) into muscle cells called myofibres.

5 SCAFFOLDING
Myofibres are transferred to structural scaffolding, typically made from collagen or gelatin, to grow into larger muscle fibres and form meat tissue.

CHURCHILL'S PREDICTION

The concept of cultured meat isn't a new idea; it's not even one dreamt up in this century. Years before he faced one of the most significant wars in history, UK prime minister Winston Churchill was known for writing predictive essays on the state of humankind. In one such essay, entitled *Fifty Years Hence*, which was published in *The Strand Magazine* in 1931, Churchill predicted that as scientific understanding grew, we may no longer need the whole animal, only growing parts for food. In the essay, he writes: "With a greater knowledge of what are called hormones, the chemical messengers in our blood, it will be possible to control growth. We shall escape the absurdity of growing a whole chicken to eat the breast or wing by growing these parts separately under a suitable medium." It took 82 years, but in 2013 the first lab-grown meat product, a burger, was created by scientists in the Netherlands.

Before World War II, Churchill predicted that we would one day culture our own meat

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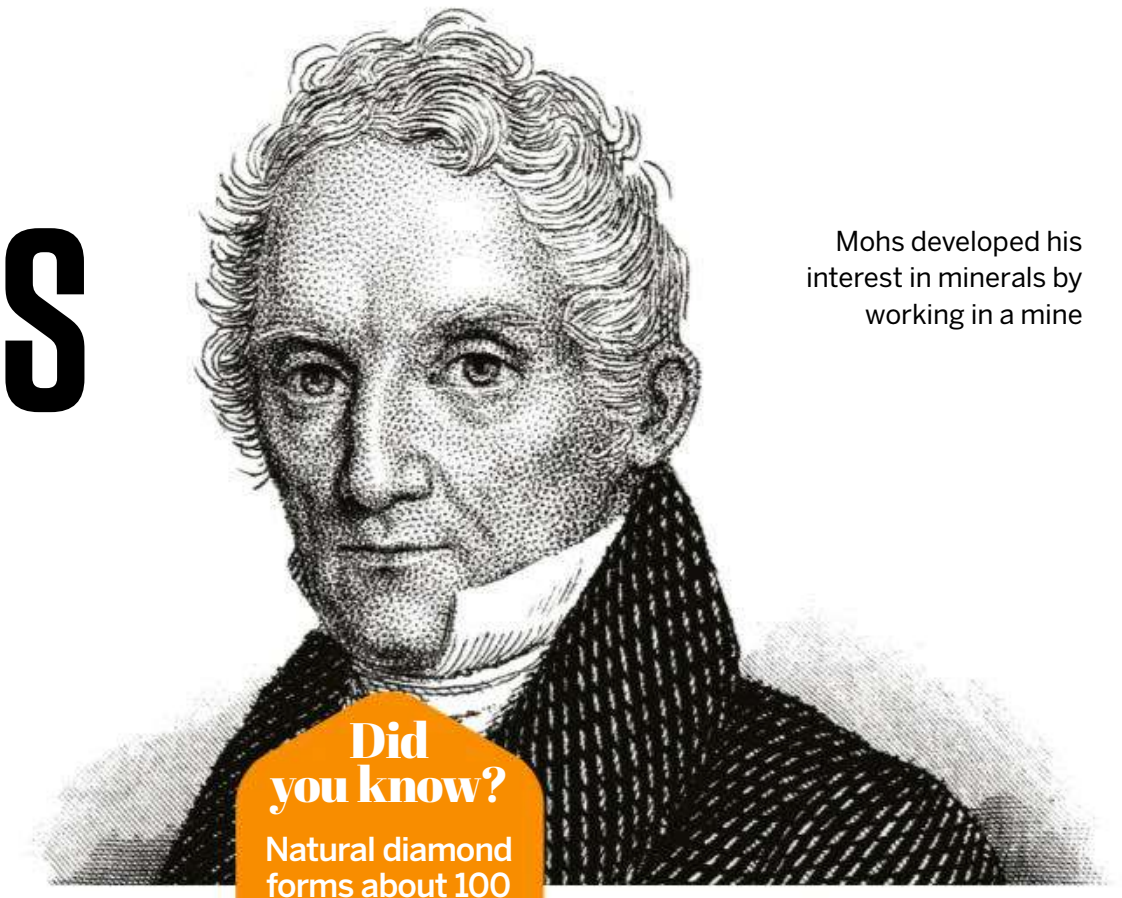
HOW HARDNESS IS MEASURED

This scale helps scientists identify and categorise minerals

WORDS **AILSA HARVEY**



Mohs developed his interest in minerals by working in a mine

Did you know?

Natural diamond forms about 100 miles beneath Earth's surface

The Mohs hardness scale is a simple but effective ten-point scale that ranks minerals according to their hardness. It was devised by German mineralogist Friedrich Mohs in 1822 and places the softest minerals down the bottom at 1.0, while 10.0 indicates the hardest minerals, like diamond. Mohs gave ten minerals of increasing hardness arbitrary values in order to create a template for testing all other minerals.

To determine the hardness of a material, it's scratched by minerals of a known value. Hardness is measured by a solid material's resistance to scratching and abrasion from a harder substance. For example, if a mineral can be scratched by apatite, known to have a value of 5.0 on the Mohs scale, but can't be scratched by fluorite, which is 4.0 on the scale, then the tested material lies between 4.0 and 5.0.

Often, minerals can't be determined by their appearance alone, so the Mohs scale was devised to help identify unknown minerals. Geologists, who are aware of where minerals lie on the scale, use the scratch test to determine what mineral its hardness rating aligns with. As the hardness rating increases, the scale increases exponentially. For example, 9.0 is twice as hard as 8.0, but 10.0 is four times as hard as 9.0.

SCRATCHING MINERALS

How do these rocks rank on the scale?

1.0 TALC
Talc is white-grey in colour and is usually translucent. It's easy to scratch with a fingernail.

2.0 GYPSUM
This is slightly harder to scratch with a fingernail. Gypsum is a soft sedimentary rock made of calcium sulphide.

3.0 CALCITE
Making a scratch in this mineral with a penny is difficult, but a knife succeeds easily. It's white when pure.

4.0 FLUORITE
A penny cannot scratch fluorite, but a knife can. Different colourings are caused by impurities.

5.0 APATITE
Apatite is present in your teeth and bones. A knife can scratch apatite, but with difficulty.

6.0 FELDSPAR
A knife is unable to mark it, but glass can with difficulty. This mineral contains silicon and aluminium.

7.0 QUARTZ
A piece of this clear, crystalline mineral can easily scratch glass. The atoms inside are tightly packed.

8.0 BERYL
Beryl, a mineral containing beryllium, aluminium and silicate, can range from 7.5 to 8.0.

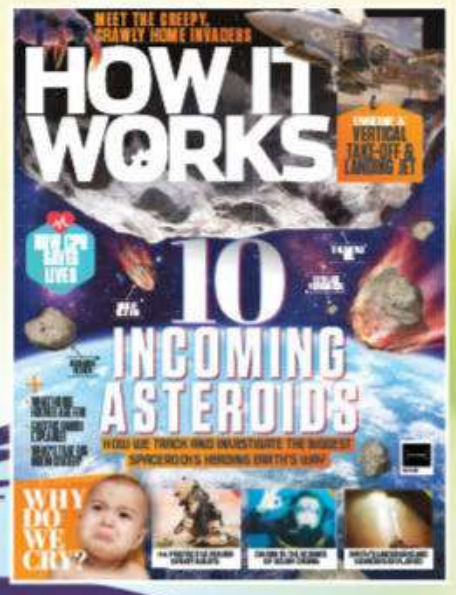
9.0 CORUNDUM
This aluminium oxide mineral can exist in a range of colours. It is very hard and can cut glass.

10.0 DIAMOND
Pure carbon atoms have a strong arrangement in this mineral. Only another diamond can scratch it.

© Alamy / Getty

Summer Savings

SIZZLING HOT SUBSCRIPTIONS



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woman & home
CLARE BALDING
High-street MUST HAVES
50 fabulous fashion finds under £50
AMAZING WOMEN AWARDS
TOO AFRAID TO ASK?
KEEPING UP WITH THE JONESES
ENJOY THE SUN
A TASTE OF SUMMER
Easy barbecue ideas to please a crowd
Showstopping cocktails to share
PLUS smart solutions for small gardens

POCHETTINO • PETIT • PARMA IN THE '90S
FourFourTwo
HAALAND MARTINEZ GVARDIOL OLISE RICE SAKA
RASHFORD MITROVIC MADRISON TONEY SALAH KANE
THE 50 BEST
PREMIER LEAGUE PLAYERS
CHARLTON 4-4 SUNDERLAND • HYPNOTISM • CARBONE

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MOTORBIKE EVOLUTION

From simple early designs to today's speedy sporting tech, these two-wheeled vehicles have stepped up a gear

WORDS **AILSA HARVEY**

DID YOU KNOW? By 1920, Harley-Davidson had 2,000 dealers in 67 countries

1885: THE FIRST MOTORBIKE

Described as the first true motorbike, the 1885 Daimler Reitwagen was the earliest motorcycle to be successfully powered by a petrol engine. The Reitwagen bike, which means 'riding wagon' in German, was engineered by inventors Gottlieb Daimler and Wilhelm Maybach. Daimler is considered to be the 'father of the motorcycle' despite three similar models being invented prior to the Reitwagen. This is because they were steam-powered and didn't fit the definition of a modern motorcycle: a two-wheeled vehicle with an internal combustion engine.

The Reitwagen had a single four-stroke 264cc (cubic centimetre) engine. Its maximum speed of 6.8 miles per hour is nothing compared to today's superbikes, hitting speeds of over 200 miles per hour. Despite being classed as a motorbike, the two-wheeled Reitwagen required additional small wheels as stabilisers to keep it upright when turning corners. Nevertheless, the low speeds and mobility issues were overlooked for this motorbike's innovations, and the Reitwagen served as a template for future motorbikes, sparking the evolution of more mobile and efficient models.

The Reitwagen's engine produced 0.5 horsepower at 600 revolutions per minute (rpm)

The De Dion-Bouton motor tricycle had a single-cylinder 138cc engine

1897: DE DION-BOUTON MOTOR TRICYCLE

Between 1897 and 1901, 15,000 De Dion-Bouton motorbikes were sold. This was the first major surge in motor vehicle sales. The three-wheeled bike was inspired by its predecessor, the Reitwagen, and caused manufacturer De Dion-Bouton to focus on gasoline engines. The bike's frame was designed for a pedal bike with an engine, ignition, battery and three-litre fuel tank. With a full tank, the bike could travel around 43 miles before refuelling. By the end of the decade, the motor tricycle was popular as the fastest available form of motor transport. It could travel over double the speed of the first motorbike, at 21 miles per hour.

Did you know?

The world's longest motorbike is 26.29 metres long

In 1905, the first prototype won a 15-mile race in Chicago

1905: THE RISE OF HARLEY-DAVIDSON

Harley-Davidson is still an iconic name in the world of motorcycles. The motorbike manufacturer has been around for over a century and is the largest in the world. The Harley-Davidson Model 1 was the first motorbike produced by the company, built in 1903 and launched in 1905. This bike wasn't as smooth as the Harley-Davidsons you may be familiar with today. To get the vehicle up and running, the rider would need to pedal until the air in the single-cylinder engine was compressed enough for fuel ignition. When sufficient pedalling had taken place to fire up the engine, it would deliver power to the motorbike. By 1909 this engine was replaced by a two-cylinder engine that could carry the rider up to 60 miles per hour. These machines were much more successful, and 3,200 were produced by 1910.

© Alamy / Getty

5 MAJOR MOTORBIKE MOMENTS

1 HORIZONTAL ENGINES

In 1921, the Moto Guzzi Normale bike was released. This was the first Moto Guzzi model and demonstrated early use of horizontal engines in motorbike design. By laying the engine on its side, it had a lower centre of gravity and minimised the vibration felt when riding.

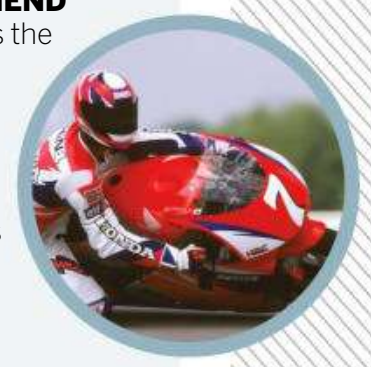
2 FIRST SUPERBIKE

The Brough Superior SS100 was the world's first superbike, or high-performance motorbike. It was built with a guarantee to drive faster than 100 miles per hour, which was extremely rare for any motor vehicle at the time.

3 SPORT BIKE HANDLING

Honda's FireBlade CBR900RR sport bike was built with weight-saving as the main priority. Revealed in 1992, the bike was powered by a 750cc engine and was the lightest and most compact in its class.

4 GRAND PRIX LEGEND



The Honda NSR500 is the most dominant Grand Prix motorbike in modern racing. Between 1984 and 2002, ten 500cc World Championships were won by this model, with over 100 wins in total.

5 LIGHTWEIGHT TECH

This futuristic-looking lightweight motorbike is called the Kawasaki Ninja 400. The sportbike is the largest in the 399cc category, but is also one of the lightest motorcycles on the market at just 168 kilograms.

TWO-WHEEL ENGINEERING

Explore the basic anatomy and modern features of today's motorcycles

Did you know?

Wearing a helmet while riding became law in the UK in 1973

4 STORAGE

While some bikes have a second seat for a passenger, others have a storage compartment that can be flipped open when unlocked.

3 SEAT SHAPE

Modern motorbike seats are curved at the edges for comfort. Older bikes with flatter seats required much more foam and a narrowed front.

5 EXHAUST PIPE

Exhaust fumes exit the bike at the back, directed away from the rider.

7 CHAIN

A robust chain connects the motor and the rear wheel of motorbikes. As the chain is turned by the motor, it links to projections called sprockets at the centre of the rear wheel. This drives the rotation of the wheels.

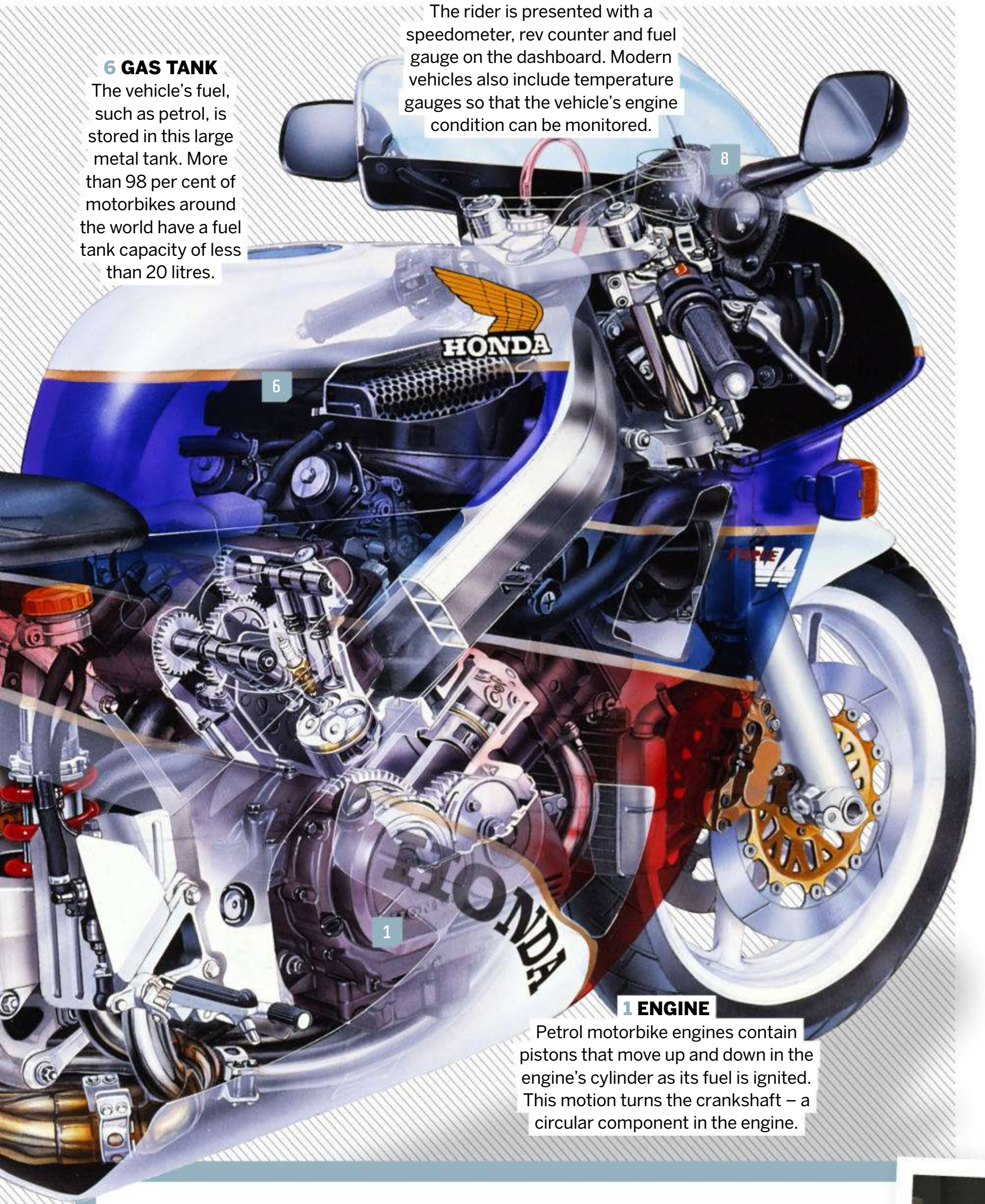
2 WHEEL MOTION

The rotational force of the engine's turning crankshaft is transmitted to the rear wheel. As this turns, the motorbike moves.

DID YOU KNOW? Troops used motorcycles in World War I to evacuate wounded soldiers and for message dispatching

8 DASHBOARD
The rider is presented with a speedometer, rev counter and fuel gauge on the dashboard. Modern vehicles also include temperature gauges so that the vehicle's engine condition can be monitored.

6 GAS TANK
The vehicle's fuel, such as petrol, is stored in this large metal tank. More than 98 per cent of motorbikes around the world have a fuel tank capacity of less than 20 litres.



1 ENGINE
Petrol motorbike engines contain pistons that move up and down in the engine's cylinder as its fuel is ignited. This motion turns the crankshaft – a circular component in the engine.

MOTORBIKE TYPES

STANDARD
These have a simple structure and are usually multi-purpose, with 125cc to 1,000cc engines.

CRUISER
Cruisers have a lower seat and are designed for people who like to ride around town in style.

TOURING
These bikes are good for cross-country travelling and are one of the largest types of bike.

SPORTS
Racing motorbikes are engineered so that the rider is leaning forward in a streamlined position.

OFF-ROAD
Off-road motorbikes have higher suspension than other bikes, and the tyres have extra grip.

DUAL-PURPOSE
These bikes aim to tackle both on-road and off-road conditions.

WHAT ARE SMART HELMETS?

Helmets are one of the most vital pieces of equipment a motorcyclist can own. By wearing one, the risk of suffering a significant head injury is reduced by around 70 per cent. Smart motorbike helmets help keep bikers safe, focused and connected when commuting or racing. With speakers and microphones, these tech-filled head protectors allow riders and passengers to communicate without taking their eyes off the road. Modern helmets also incorporate augmented reality, activated by voice commands. Displayed on the visor, smart helmets can show directions, traffic updates and alert the wearer to hazardous weather. A rear-facing camera built into the helmet also provides motorcyclists with 360-degree views when necessary, all while keeping their main focus on the road ahead.

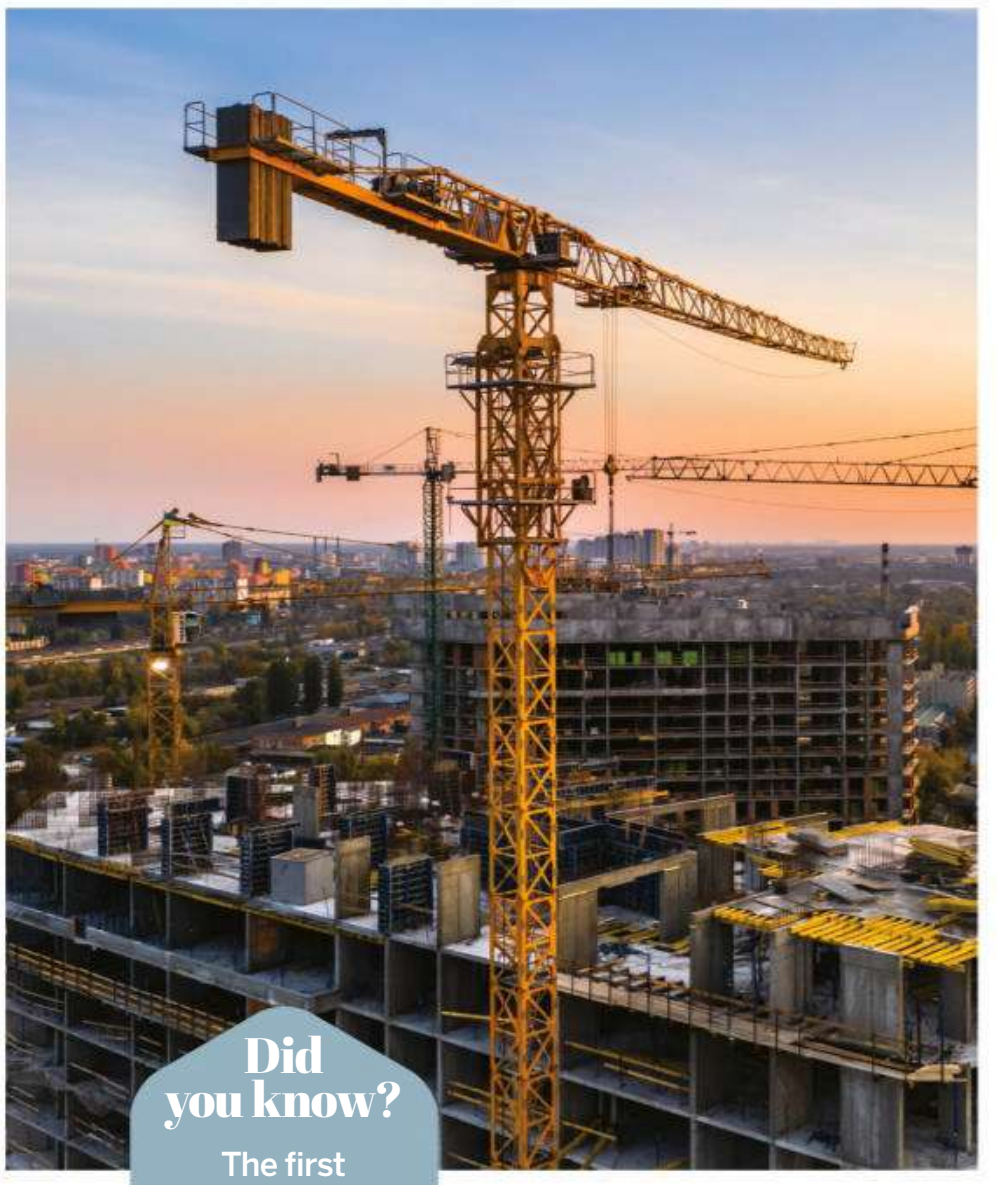
CrossHelmet includes a touchscreen panel at the side to make answering calls easier, and a rear-view camera

© Alamy / Getty / Honda / Wikimedia Commons: Serge PIOTIN

HOW A CONSTRUCTION CRANE WORKS

Incredible engineering allows these lofty lifters to hoist hefty materials into the air with ease

WORDS **AILSA HARVEY**



Without construction cranes, modern urban landscapes wouldn't exist. Cranes are one of the most essential tools in large-scale construction and have shaped the cities we know today. Before these weight-handling machines were invented, buildings were restricted by the limits of human strength. This limited the size of communities and the scale of their monuments. Relying on human power also meant that much larger groups of workers were required for each new build. On a construction site today, a small selection of highly skilled builders operate cranes and other similarly sophisticated machinery.

The energy used to lift, hold, turn and lower building materials is generated in the crane's engines. These can be in the form of an internal diesel combustion engine or electric motors. Multiple motors are required for hoisting, luffing, slewing and long travel motions. Hoisting is the action of lifting and lowering materials by rotating the metal rope-like extension that it's attached to. Luffing also involves moving the material vertically, but by adjusting the crane's arm instead of the hoist. Motors that control slewing rotate the turntable where the top of the crane's tower meets the horizontal arm. This swings the lifted object towards or away from the building area. The final motion is reduced to smaller cranes that can move around to change their base area. This movement along ground surfaces aids the lift work in construction along roads.

Did you know?

The first powered crane was built in 1850

FIVE LARGEST CRANES

BIG CARL

SGC-250, known as Big Carl, is considered the world's largest crane, with a reach of 275 metres. 52 counterweight containers weighing 100 tonnes each assist the Belgian crane in lifting the equivalent of 1,600 family cars at a time.

TAISUN CRANE

This 133-metre-tall crane in Yantai, Shandong Province, China, holds the world record for the heaviest weight lifted at 20,133 tonnes.

KONECRANES GOLIATH GANTRY CRANE

A Goliath Gantry Crane has wheeled legs on either side in order to move along a track or rail. One such crane in Rio Grande do Sul, Brazil, can lift 2,000 tonnes and spans a huge 210 metres of rail.

TRIPLE THREAT

Three large shipping container cranes at Port Everglades, Florida, are the largest of their kind in the world. Each one is 53 metres tall and can reach 22 containers from a docked ship.

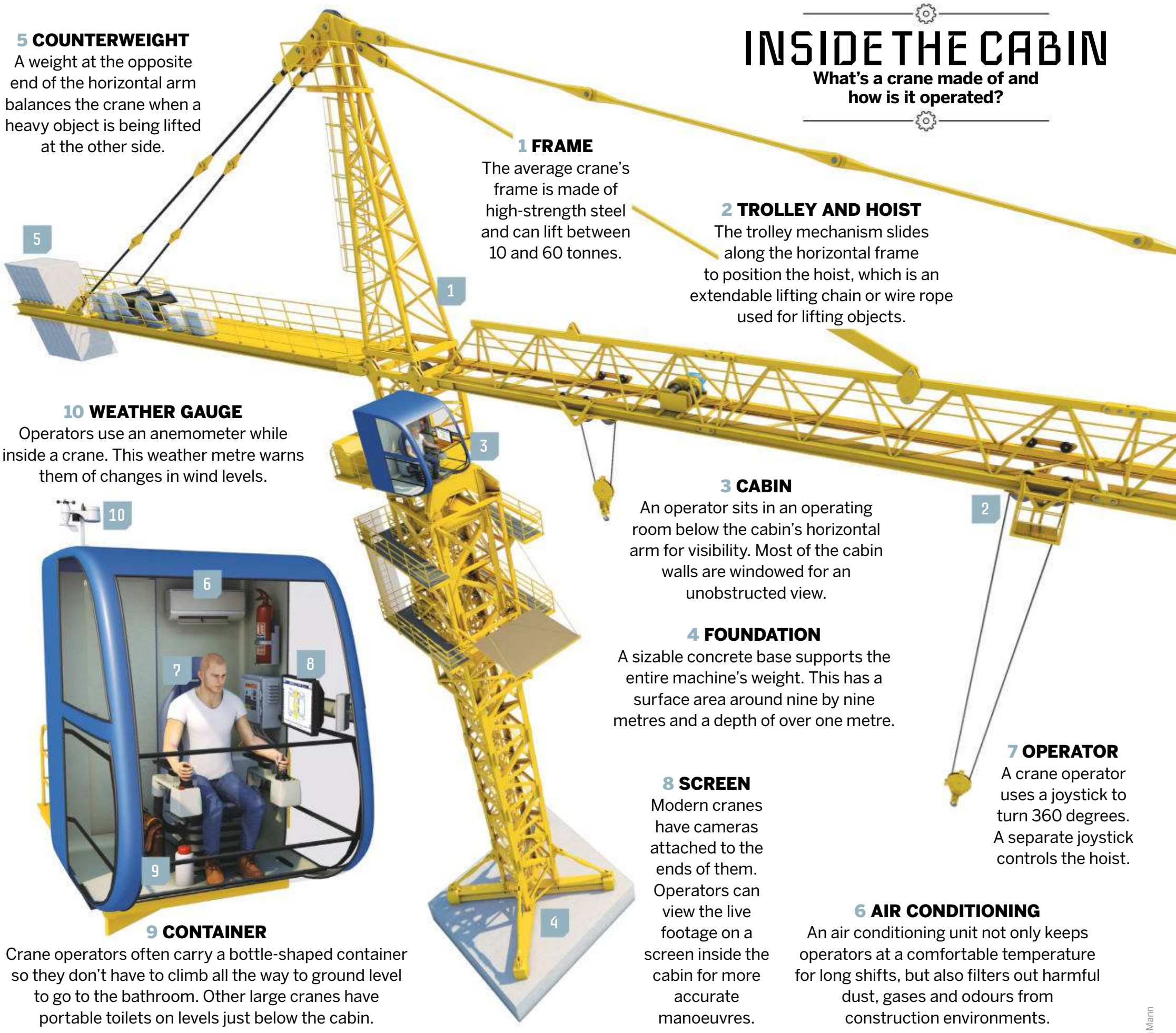
KOCKUMS GANTRY CRANE

Between 1973 and 2002, the Kockums Gantry crane stretched 140 metres across Saab Kockums shipyard in Malmo, Sweden, and lifted 1,500 tonnes. In 2002 it was dismantled.

DID YOU KNOW? Of the 200,000 cranes in the world, 125,000 are used in construction

INSIDE THE CABIN

What's a crane made of and how is it operated?



5 COUNTERWEIGHT
A weight at the opposite end of the horizontal arm balances the crane when a heavy object is being lifted at the other side.

1 FRAME
The average crane's frame is made of high-strength steel and can lift between 10 and 60 tonnes.

2 TROLLEY AND HOIST
The trolley mechanism slides along the horizontal frame to position the hoist, which is an extendable lifting chain or wire rope used for lifting objects.

10 WEATHER GAUGE
Operators use an anemometer while inside a crane. This weather metre warns them of changes in wind levels.

3 CABIN
An operator sits in an operating room below the cabin's horizontal arm for visibility. Most of the cabin walls are windowed for an unobstructed view.

4 FOUNDATION
A sizable concrete base supports the entire machine's weight. This has a surface area around nine by nine metres and a depth of over one metre.

7 OPERATOR
A crane operator uses a joystick to turn 360 degrees. A separate joystick controls the hoist.

8 SCREEN
Modern cranes have cameras attached to the ends of them. Operators can view the live footage on a screen inside the cabin for more accurate manoeuvres.

6 AIR CONDITIONING
An air conditioning unit not only keeps operators at a comfortable temperature for long shifts, but also filters out harmful dust, gases and odours from construction environments.

9 CONTAINER
Crane operators often carry a bottle-shaped container so they don't have to climb all the way to ground level to go to the bathroom. Other large cranes have portable toilets on levels just below the cabin.

STATIC VERSUS MOBILE

Some cranes are anchored to the ground or are fixed to the roof of a building, ready to pass heavy items across a predetermined trajectory in each unloading. This is called a static crane and is deployed for roles such as constructing tall buildings, where the height is adjusted in each lift but the destination of material is in the same vicinity throughout. Other construction cranes are mobile and need to travel between locations to carry materials around.

The most common type of static crane is a tower crane, consisting of a large vertical tower, or mast, and horizontal arm that extends out from it, called the jib. These substantial towers are fixed to one spot, making them the stronger type. But what static cranes gain in strength, they lack in flexibility. Mobile cranes are usually mounted onto heavy tracked vehicles and can transport material over grounds of varying softness and waterlogged construction landscapes.

Mobile cranes are usually used to erect steel structures and unload ships.

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DIGGING THE CHANNEL TUNNEL

How one of the world's longest undersea passages came to be

WORDS **SCOTT DUTFIELD**

One of the French TBMs used to dig the Channel Tunnel

In 1988, engineers took the first swing at a face of rock that would one day be carved into the opening of one of the longest rail tunnels in the world. The Channel Tunnel, also referred to as the Chunnel, is a 31.35-mile-long tunnel that runs from Folkestone in Kent, England, and ends in Pas-de-Calais, France. However, unlike many other rail tunnels, 24 miles of the tunnel is buried beneath the water of the English Channel. The construction was completed by companies from both England and France in a collaboration called the Anglo-French consortium Transmanche Link (TML). It took six years to construct the three parallel tunnels that form the Channel Tunnel – two larger rail tunnels and a smaller service tunnel for ventilation and maintenance access.

The tunnel sits around 45 metres below the seabed on average, with the lowest point reaching 75 metres, highlighting that the tunnel's architects had to carefully consider the geology around it. After examining the layers of rock below the seafloor of the Channel, engineers concluded that a band of rock beneath the seabed called the Chalk Marl would be the best route to connect the UK to mainland Europe. Enormous tunnel boring machines (TBMs) were used to excavate the Chalk Marl and remove the resulting debris. There were 11 TBMs used to build the tunnel – five from France and six from the UK – most of which were more than 220 metres long and weighed up to around 15,000 tonnes. The TBM cutter heads chipped away at the Chalk Marl at more than 800 metres per month. The chalk excavated from the construction of the English side was landscaped into a nature reserve at the base of Shakespeare Cliff between Folkestone and Dover, known as Samphire Hoe. The French, on the other hand, used the chalk to create a new landscaped hill near the tunnel entrance on their side.

Did you know?

400 trains use the tunnel each day

1 ABOVE THE TUNNEL
At its lowest point, the Channel Tunnel sits 115 metres from the grey chalk surface of the English side.

2 CHALK MARL
The Channel Tunnel runs through a continuous band of rock called Chalk Marl, which is a mixture of cemented clay and chalk that's between 15 and 30 metres thick.

4 WALLS
The tunnel is made from cast iron segments that have been bolted to concrete rings.

5 TUNNEL BORING MACHINE
A spinning cutterhead that burrows into the bedrock and an internal conveyor belt system that feeds the debris, or spoil, out through its rear for removal.

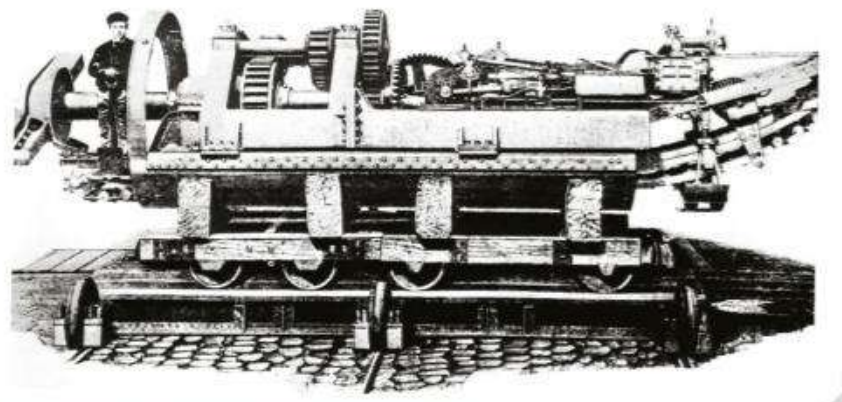
BENEATH THE CHANNEL

How the Channel Tunnel connects the United Kingdom to the rest of Europe

DID YOU KNOW? The Channel Tunnel cost £4.65 billion – almost £10 billion today – to construct

THE TUNNEL THAT NEVER HAPPENED

The modern-day Channel Tunnel wasn't the first attempt at creating a connection from Britain to mainland Europe. In 1880, engineers at the base of Abbot's Cliff in Kent began digging a tunnel that they thought would finally cross the English Channel and tether England to France. To construct the pioneering tunnel, a compressed-air boring machine, known as the Beaumont boring machine, was lowered into a shaft just a few metres deep. Once inside the shaft, the moving blades affixed to the front of the machine cut into the rock. However, it only made it just over a mile before the project ended. What brought the construction of the tunnel to a halt was not a technical fault or geological hurdle, but rather the fears of parliament. After contemplating the impact of a physical connection to mainland Europe, concerns grew about national defence and the risk of potential future invasions, so the project was shut down in 1882.



An illustration of the Beaumont boring machine used in the first incomplete Channel Tunnel

United Kingdom
Dover
Folkestone
Strait of Dover
Pas-de-Calais
Channel Tunnel
Calais
France
It takes just over two hours to travel by train through the Channel Tunnel to reach France from the UK
3 GLAUCONITIC MARL
This is a supportive band of sandstone that is much stronger than the chalk.
7 TRAIN TUNNELS
Both of the main transport tunnels are around 30 metres apart from each other – one is for foot passengers and the other transports vehicles along the tunnel.
6 SERVICE TUNNEL
Used for ventilation, to make repairs and to make emergency rescues when required.
3
7
6

IMMERSIVE FUTURE

2029 is set to see the opening of an underwater tunnel unlike any other. Connecting northern Germany with the Danish island of Lolland, the Fehmarn Belt fixed link will cross more than 11 miles and allow people to travel from Puttgarden in Germany to Rødbyhavn in Denmark in just seven minutes. The traditional boring method of tunnel construction is thought to be unsuitable for the connecting geology. To overcome this construction hurdle, engineers have designed a tunnel that comprises 89 hollow concrete sections that are lowered onto the seafloor and connected. The tunnel will be laid around 40 metres below the surface of the Baltic Sea and will include separate railway and motorway tunnels. Construction began in January 2021, and it's estimated it will cost almost £6 billion (€7 billion) at the time of completion.

An illustration of the immersion and connection between two tunnel sections

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ENVIRONMENT

HOW LIFE EVOLVES

Discover the biological pathways through time that led to the plants and animals of today

WORDS **SCOTT DUTFIELD**

DID YOU KNOW? The average human brain is 110 to 150 cubic centimetres smaller than the when our species first emerged

For around 3.7 billion years, life has followed a roadmap of evolution. The journey to modern-day life and the more than 2.16 million known species that reside on Earth has been guided by several different evolutionary pathways. The naturalist known as 'the father of evolution', Charles Darwin, first proposed the theory of evolution by natural selection after he jumped aboard the HMS Beagle in 1831 and sailed around the world for five years. On his travels, he discovered diverse wildlife, observing that they had anatomy specially adapted to their environments. He concluded that a species' survival depends on traits that suit its environment. This survival-of-the-fittest approach means that only animals with beneficial characteristics can continue to reproduce and pass them onto their offspring. Darwin proposed that through forces of evolution, an ancestral family tree formed below modern-day species, leading to a common ancestor at its roots.

Did you know?

The first reptiles evolved around 315 million years ago

Forces of evolution are varied and specific to an ecology niche. For many, evolution is driven by sexual selection, whereby qualities in potential mates – such as plumage vibrancy or big antlers – are chosen by a partner to successfully reproduce. For others, natural selection occurs when an aspect of a species' environment is altered, such as by climatic change, and they are forced to adapt or die. Those that can change go on to reproduce, leading to some

© Getty

Birds and bats both evolved separately, resulting in wings despite having different lineages

Honey badgers evolved thick skin to evade the sting of a bee, but bees co-evolved a signalling system to attack badgers en masse

anatomical and behavioural differences over millennia, creating new species along the way. Today scientists refer to the creation of a new species as divergent evolution, where a new species separates from a common ancestor. Building on the work of Darwin, the term 'divergent evolution' was first introduced by evolutionist John Thomas Gulick in 1890. As the name suggests, divergent evolution occurs when a subgroup within a species diverges anatomically from the rest of the species, with these genes spreading until a new distinct species emerges. All life on Earth has undergone divergent evolution from a distant common ancestor, branching off into new families that form the tree of life.

For example, humans share more than 97 per cent of their DNA with the other great ape species on Earth: orangutans, gorillas and chimpanzees. Evolving from a common ancestor more than 25 million years ago, the great apes have diverged from their common lineage to produce an unknown number of now-extinct species that have paved the way for modern-day animals. Although they share a common ancestor, each ape has evolved distinctly different characteristics that have benefited them in their environment but have ultimately led to development of each individual ape species.

Divergent evolution occurs over long periods, with some studies suggesting that it generally takes around 2 million years for a new species to emerge. However, not all animals are willing to wait that long, instead rapidly evolving several new species through a process known as adaptive radiation. One of Darwin's most notable observations involved a group of finches that lived throughout the Galápagos Islands. Across the different islands, Darwin observed that among the related finches, beak size and shape varied depending on what food they ate. He concluded that with each new generation, those that were better equipped to find food were able to survive – a concept that formed the basis for his theory on natural selection.

Similarly, in Hawaii, a group of birds called honeycreepers have undergone adaptive radiation to produce a diverse family of birds with beaks specialised for their food. Some boast big, long beaks to probe underneath bark to find insects, while others developed stout robust beaks for

HUMAN FAMILY TREE

The road to becoming one of the great apes of the world

1.8 MILLION YEARS AGO
The formation of the Congo River formed a barrier, splitting chimpanzees into two groups, one of which evolved into the modern-day bonobo.

6 MILLION YEARS AGO
The evolutionary path of humans diverged from a primate ancestor shared with one of our closest living relatives today, the chimpanzee.

6 TO 8 MILLION YEARS AGO
Gorillas diverged from hominids. As more species of apes became extinct over time, gorillas evolved to become the largest of the great apes.

12 TO 16 MILLION YEARS AGO
Orangutans diverged from other apes of the Hominidae family in Asia, while the ancestors of the other great apes stayed in Africa.

COMMON ANCESTOR
Though an exact common ancestor is unknown, a primate in the family Hominidae is responsible for starting the journey of ape evolution.

cracking seeds and picking berries. Upon reaching Hawaii around 3 million years ago, the common ancestor of the honeycreeper species wasted no time adapting to the array of food sources found across the archipelago. Within 2 million years, 50 species of honeycreeper emerged. But only 17 species remain today.

Where divergent evolution leads to the creation of entirely new species from a common ancestor, another evolutionary pathway, known as convergent evolution, produces new species that have evolved surprisingly similar traits. At first glance you might forgive early biologists for mistaking dolphins for fish, or bats for a member of the bird family. That's because they share similar characteristics: dolphins evolved fish-like fins to swim, and bats developed bird-like wings for flight. However, dolphins and fish do not share a common ancestor, and neither do birds and bats. The two have completely separate evolutionary lineages, yet both developed similar anatomical features, known as analogies.

When two species occupy the same ecological niche, and are therefore subject to the same evolutionary pressures, both evolve and adapt in similar ways, over time changing into new species that bear a resemblance to one another. For birds, the ability to fly emerged around 160 million years ago when the earliest known bird, a long-feathered dinosaur called *Archaeopteryx*, flapped its long feathers – which covered the skin of dinosaurs for millions of years. The elongated length of this dinosaur's arms helped generate some lift beneath them, allowing it to fly for short periods of time, in a similar way to a modern-day pheasant. Flight gave *Archaeopteryx* an advantage over other animals when evading predators, and also hunting prey from treetops. Bats, on the other hand, evolved only 50 million years ago, descending from an unknown mammal species. Scientists think that bats evolved from small tree-dwelling mammals that eventually developed flaps of skin between their toes called interdigital webbing. This interdigital webbing eventually evolved into wings that not only allowed them to glide from tree to tree, but actively generate lift like a bird and fly.

Beneath the umbrella of divergent evolution there are microevolutions that can lead plants and animals down an evolutionary path that intertwines with another. Known as

THE HONEYCREEPERS

The birds with beaks tailored to their diets

'APAPANE
(*HIMATIONE SANGUINEA*)
These narrow-beaked birds feed on plant nectar, predominantly from the flowers of the 'ohi'a lehua tree.

KAUA'I NUKUPU'U
(*HEMIGNATHUS HANAPEPE*)
The thin hooked beaks of these birds are used to pick out insect prey that are found beneath tree bark.

'I'IWI
(*VESTIARIA COCCINEA*)
To reach the nectar of tubular flowers, these birds have evolved long curved beaks.

MAUI PARROTBILL
(*PSEUDONESTOR XANTHOPHRYS*)
Also known as a kiwikiu, these birds use their parrot-like beaks to split branches to extract insects and their larvae.

LAYSAN FINCH
(*TELESPIZA CANTANS*)
As omnivores, their beaks are used to pick fruit and seeds, as well as pick off invertebrates and even eat carrion.

LESSER 'AKIALOA
(*AKIALOA OBSCURA*)
This extinct species used its beak to hunt insects living in tree bark, inserting its entire bill into crevices.

One of Darwin's large ground finches cracking a seed

Did you know?

There are 42 dolphin species in the world

A swallowtail caterpillar looking remarkably like a green snake

© Alamy / Getty

coevolution, this phenomenon occurs when two species develop anatomical characteristics as a result of interactions with another species. These interactions typically centre around one of three processes in nature: pollination, parasitism and predation.

Pollinators such as bees and birds have evolved side by side with plant species in ways that benefit them both. For example, the pollen and nectar of the Darwin orchid (*Angraecum sesquipedale*) are found at the end of a long tube past its petals, which few pollinators could reach. Luckily, one pollinator, Wallace's sphinx moth (*Xanthopan morganii praedicta*), has evolved alongside the orchid and developed an enormous tongue called a proboscis. This can extend up to almost 30 centimetres for lapping up Darwin orchid nectar, picking up pollen along the way. It's not just the orchid that benefits – this also provides the sphinx moth with a food source other pollinators can't access.

Unlike coevolution that benefits both species, as seen in plant-and-pollinator relationships, some animals, such as Alcon blue caterpillars (*Phengaris alcon*), have co-evolved with other species in ways that make them the perfect parasites. By mimicking the scent emitted by the larvae of *Myrmica* ants, Alcon blue caterpillars can infiltrate a nest and be welcomed with open arms by the ant colony, which will then care for them as their own. Studies have also shown that when a nest is under threat, the emitted scent causes ants to prioritise the protection of the caterpillars over their own larvae.

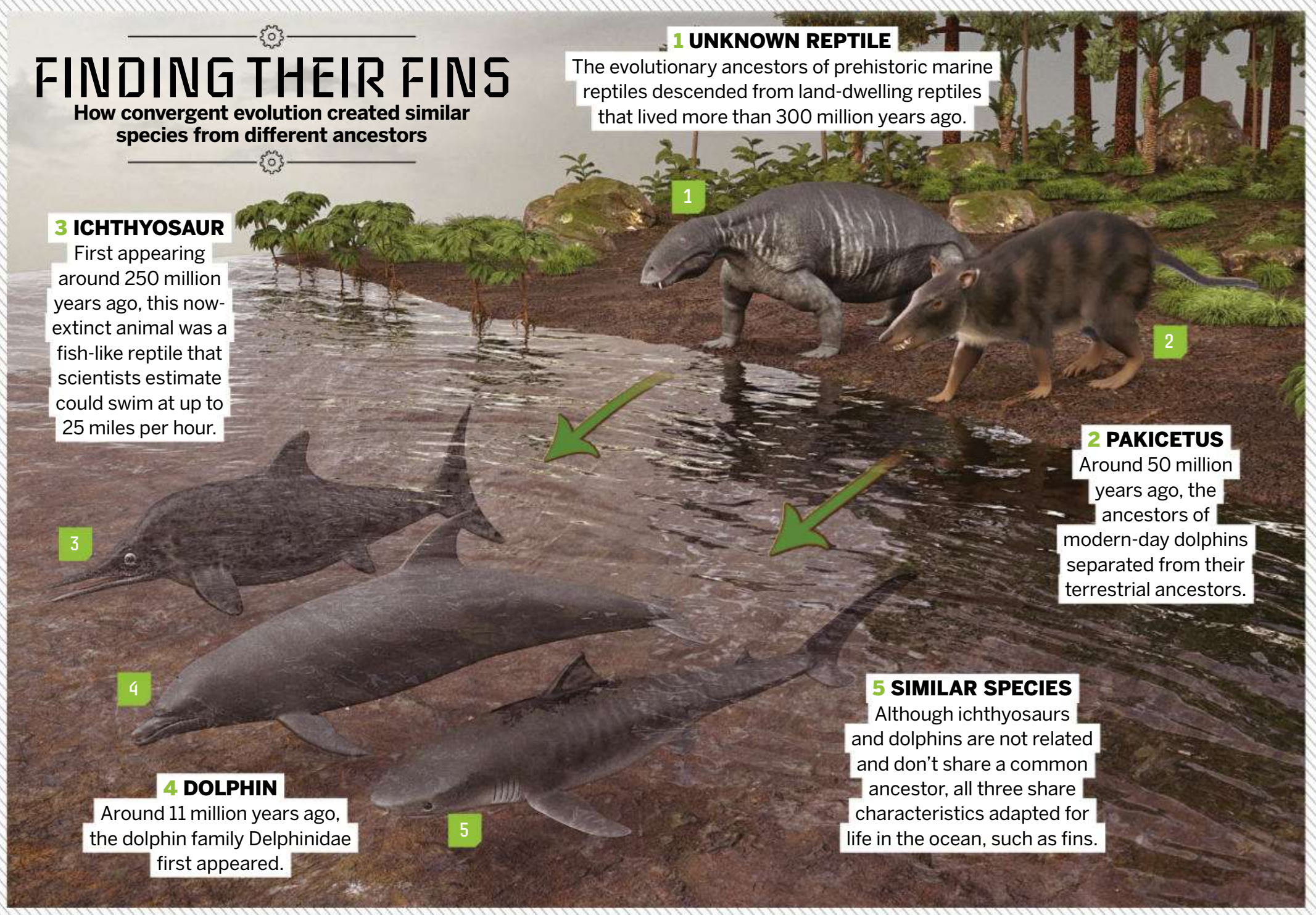
Coevolution between predators and prey provides some of the most perplexing examples of nature's ability to adapt to an environment. Typically known as Batesian mimicry, it's named after the 19th-century naturalist Henry Walter Bates and occurs when a species has evolved, behaviourally or anatomically, to mimic the characteristics of another more dangerous or venomous animal. For example, the caterpillar of the spicebush swallowtail butterfly (*Papilio troilus*) has evolved to present markings that bear strong resemblance to the head of a smooth green snake (*Opheodrys vernalis*). The purpose of displaying such a visual deception is to fool potential predators into believing that they are not the prey the predator might have hoped for, and are instead a dangerous animal that they don't want to interact with. The appearance of the spicebush swallowtail caterpillar wouldn't have the same effect without the existence of the smooth green snake, and thus the result of the snake's evolution has had a direct impact on the evolution of the spicebush swallowtail.

Did you know?

Animal pollination evolved 99.6 to 65.5 million years ago

FINDING THEIR FINS

How convergent evolution created similar species from different ancestors


1 UNKNOWN REPTILE
The evolutionary ancestors of prehistoric marine reptiles descended from land-dwelling reptiles that lived more than 300 million years ago.
1
3 ICHTHYOSAUR
First appearing around 250 million years ago, this now-extinct animal was a fish-like reptile that scientists estimate could swim at up to 25 miles per hour.
2
2 PAKICETUS
Around 50 million years ago, the ancestors of modern-day dolphins separated from their terrestrial ancestors.
3
4
4 DOLPHIN
Around 11 million years ago, the dolphin family Delphinidae first appeared.
5
5 SIMILAR SPECIES
Although ichthyosaurs and dolphins are not related and don't share a common ancestor, all three share characteristics adapted for life in the ocean, such as fins.

DID YOU KNOW? There are more than a million different known insect species, the most of any animal group on Earth

SURPRISING COEVOLUTION

Amazing examples of how two species have steered each other's evolution

The large eyes of a slow loris resemble the markings on a cobra's head

SLOW LORIS AND COBRA

These furry tree climbers are surprisingly similar to snakes and have evolved to mimic some of their notable traits. The slow loris is one of the only known mammal species to produce venom for defence, which it secretes from a gland in its elbow and then licks to create a venomous saliva in its mouth that coats its teeth. When threatened, the slow loris hisses and will cross its arms over its head, making its face, complete with large eyes, resemble the shape and markings of a cobra.

A scoliid wasp mistaking a mirror orchid for a female wasp

MIRROR ORCHID AND SCOLIID WASP

In the interest of pollination, the mirror orchid (*Ophrys speculum*) has evolved an unusual petal that attracts male scoliid wasps (*Dasyscolia ciliata*). The petal, known as a labellum, closely resembles the furry brown bodies of female scoliid wasps. Tricked into thinking he's found a mate, the male wasp lands on the flower's imitation in hope of reproducing. Instead the male wasp finds itself with a head covered in pollen as it rubs against the plant's anther, an organ that contains pollen. The wasp will then pollinate another mirror orchid when it once again mistakes its petals for another potential mate.

Fig wasps emerging from their eggs inside a fig

WASPS INSIDE FIGS

Figs produced by the fig tree (*Ficus carica*) are known as an inflorescence, not a fruit, where the inside of its bulbous body is full of clusters of small flowers and seeds. With its flowers on the inside of the fig, its only pollinator, a queen fig wasp (*Eupristina verticillata*), burrows into the fig's outer flesh and lays her eggs within before ultimately dying and being digested by the fig for nourishment. When the wasp's offspring hatch, the females gather pollen from inside the fig and take it to the next fig, where they will eventually lay their own eggs.

Cuckoo eggs are slightly larger than those in a warbler's brood

CUCKOO EGG IMPOSTERS

The common cuckoo (*Cuculus canorus*) is one of the worst parents in nature – mainly because as soon as the opportunity presents itself, female cuckoos will ditch their eggs in the nests of other birds for them to raise as their own. The presence of the Trojan egg is unknown to the host parent because cuckoos have evolved an egg colouration and speckled appearance that resembles the eggs of many other bird species, such as warblers, wagtails and pipits. The new host parent will raise the new addition until it's ready to fly the nest and continue the parasitic cycle.

© Alamy / Getty / Illustration by Nicholas Forder

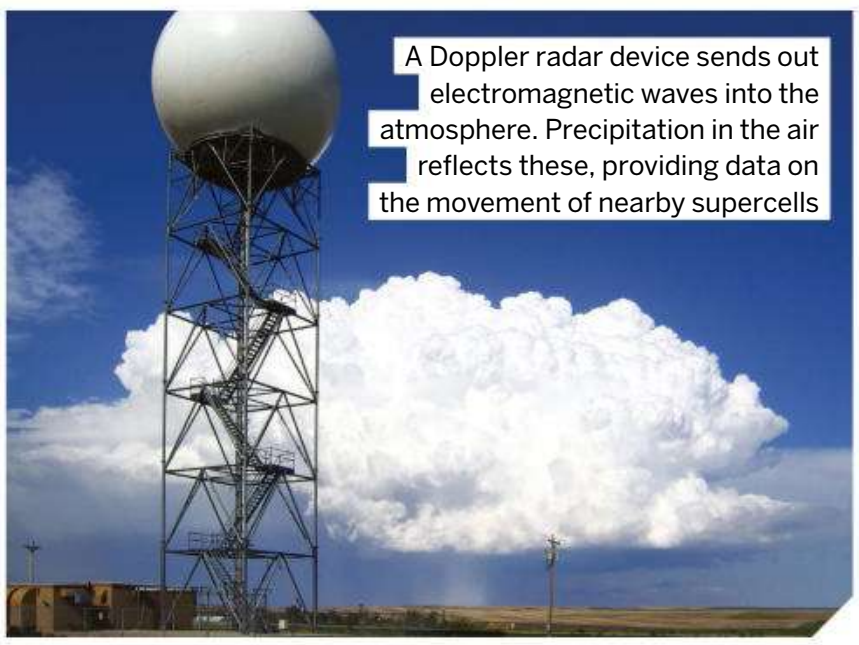
HOW STORM SUPERCELLS FORM

What turns an ordinary storm into a whirling maelstrom?

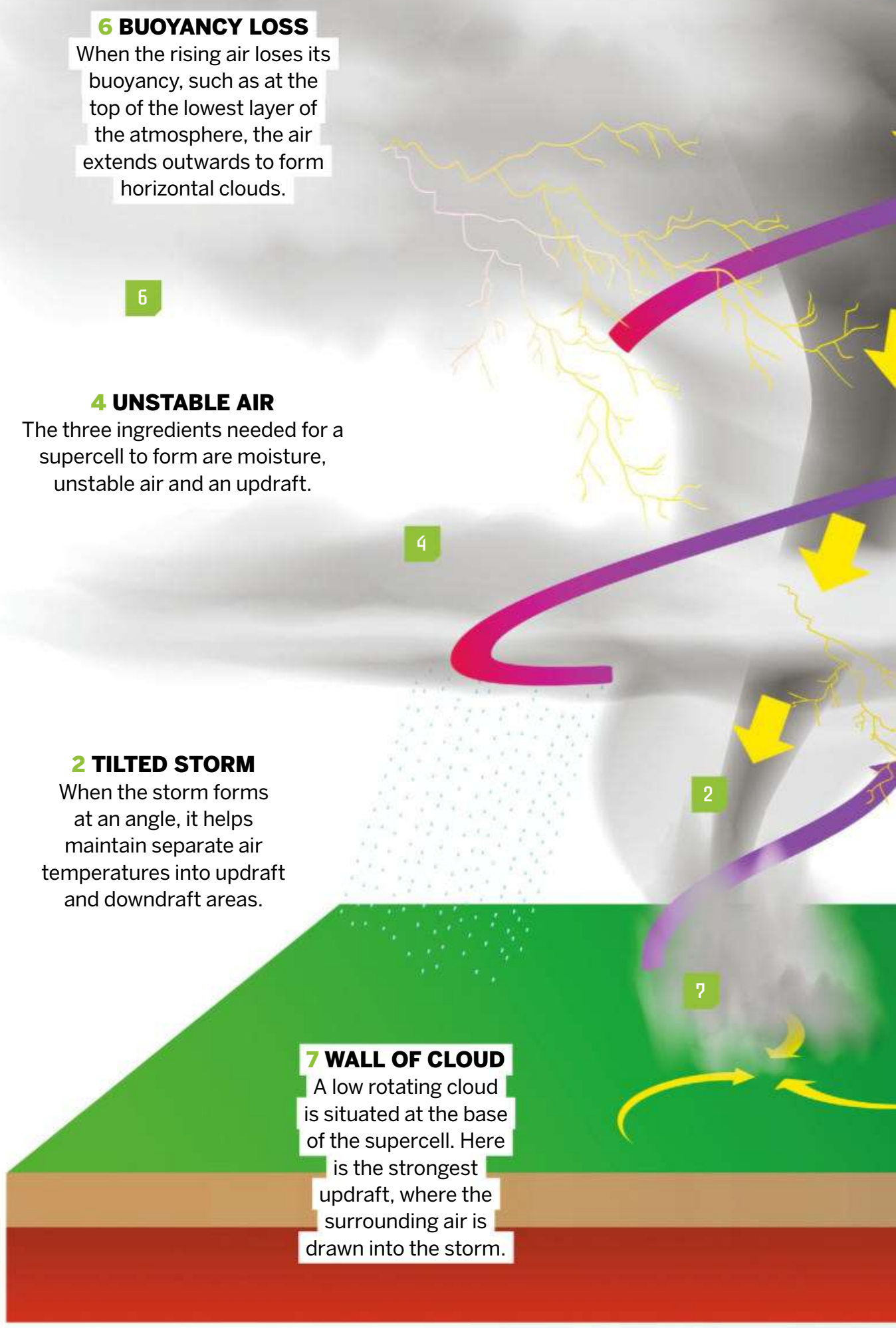
WORDS **AILSA HARVEY**

On a stormy day, if you can see a towering rod of clouds topped with a funnel-shaped horizontal cloud, there's a chance you are looking at a supercell. What separates supercells from regular thunderstorms is the rotating movement of air at the centre as it's drawn upwards to the top of the storm. Supercells are the least common form of thunderstorm. To spot a supercell in the distance, you need to observe the shape and movement of the clouds decorating them.

The most important factor that causes a supercell to form is wind shear. Wind shear is conflicting wind direction and speed that stops the air travelling smoothly straight across Earth's surface. The force of wind shear manipulates this movement into a rotating cycle. The strong winds, giant hailstones and potential to form tornadoes can make supercells a very destructive form of weather. They're most common in the central plains of the US and regularly occur during the spring season. Knowing what combination of factors form a supercell can help you stay safe and prepared for changing weather. Today, emergency services can send wireless alerts to everyone in an affected area when a severe supercell or tornado is due to pass through the region.



A Doppler radar device sends out electromagnetic waves into the atmosphere. Precipitation in the air reflects these, providing data on the movement of nearby supercells



6 BUOYANCY LOSS
When the rising air loses its buoyancy, such as at the top of the lowest layer of the atmosphere, the air extends outwards to form horizontal clouds.

4 UNSTABLE AIR
The three ingredients needed for a supercell to form are moisture, unstable air and an updraft.

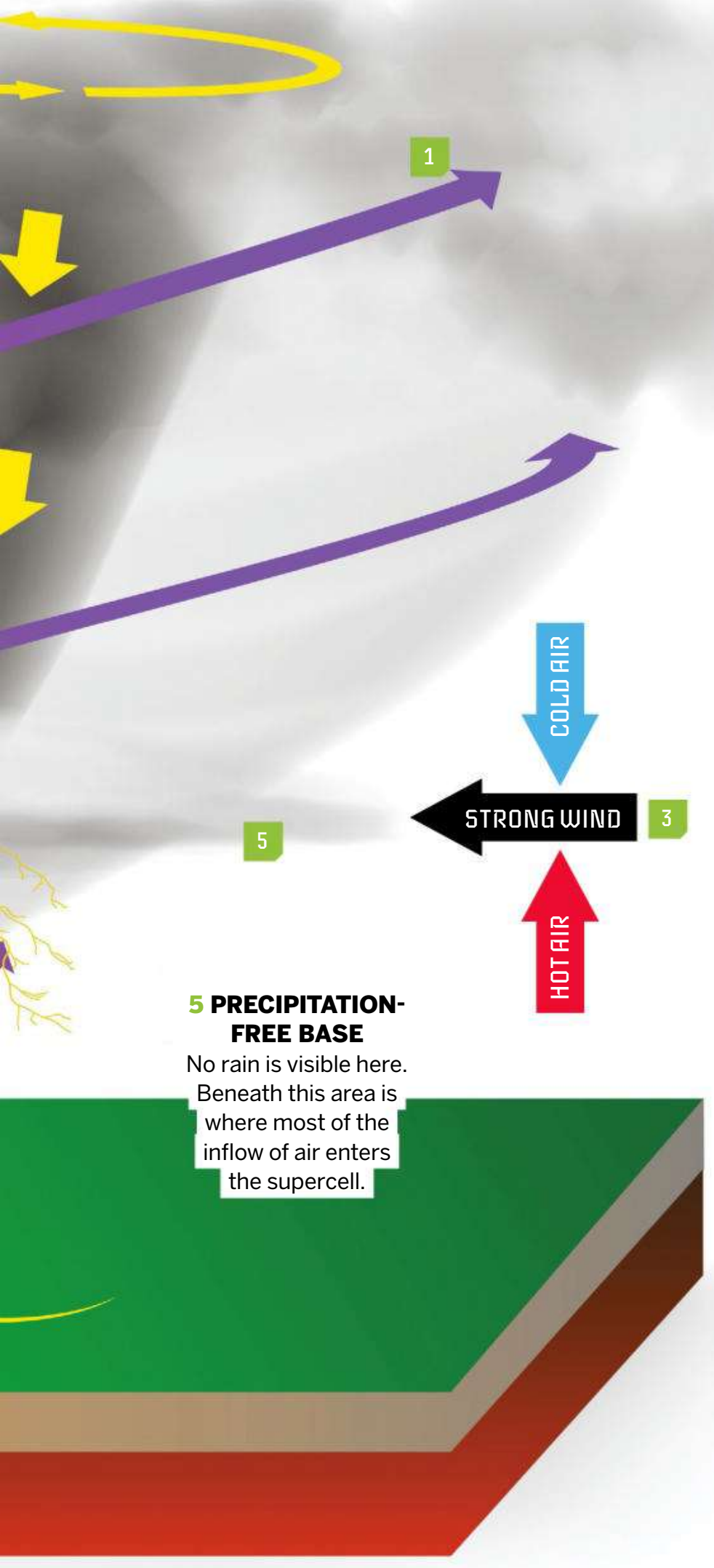
2 TILTED STORM
When the storm forms at an angle, it helps maintain separate air temperatures into updraft and downdraft areas.

7 WALL OF CLOUD
A low rotating cloud is situated at the base of the supercell. Here is the strongest updraft, where the surrounding air is drawn into the storm.

DID YOU KNOW? The largest recorded hailstone had a circumference of 47 centimetres

SUPERCELL STRUCTURE

Explore the anatomy of these surging storms



1 MESOCYCLONE
A storm is classed as a supercell when it has a continuous rotating updraft called a mesocyclone.

3 CHANGE IN WIND
When strong horizontal wind suddenly changes direction or height, the two opposing forces contort the moving air and cause it to travel in a spiral motion.

5 PRECIPITATION-FREE BASE
No rain is visible here. Beneath this area is where most of the inflow of air enters the supercell.

SUPERCELL TYPES

LOW PRECIPITATION
When the winds in the upper level of a supercell are 70 miles per hour or faster, it's classed as a low-precipitation supercell. These high wind speeds push precipitation far from the updraft of air. Low-precipitation supercells are generally more tilted and are less likely to lead to tornado formation than other types.

CLASSIC
Between 45 and 70 miles per hour, the winds of a classic supercell are slower than in a low-precipitation one. This category is where the majority of supercells form. Significant precipitation falls next to the updraft of these storms and large hailstones commonly form.

HIGH PRECIPITATION
With winds travelling slower than 40 miles per hour, high-precipitation supercells have an updraft that's surrounded by heavy rain. This type of storm commonly produces tornadoes, which the high precipitation can make difficult to see.

CREATING TORNADOES

Did you know?
Less than 20 per cent of supercells lead to tornadoes

Although many rotating storms may look like tornadoes, only some supercells transition into them. Tornadoes need a specific set of conditions to form. As they are defined as rotating air columns that make contact with Earth's surface and a thundercloud, tornadoes require the air of a supercell to spin very close to the ground in order to form. For this to occur, warm air needs to rise above the cool air at a higher altitude, which then needs to drop down to the surface enough to push the air out horizontally in gusts of wind. When this happens continuously, the air at the ground will start to spin, just as it does further up in the atmosphere in a supercell. Not all supercells that form near the ground result in tornadoes. If the air is rotating too slowly, the tornado structure will not form, while if the air is too cold near the ground, it will dissipate away from the storm's centre.

A typical tornado's damage path is around 1.2 to 1.8 miles

© Alamy / Getty / Shutterstock

ANATOMY OF A SUPERVOLCANO

Under the surface of Yellowstone National Park lurks a supervolcano that scientists now know to be twice the size they first thought – should we be worried?

WORDS **BILL MCGUIRE**

Beneath the towering forests and thundering waterfalls of Wyoming's Yellowstone National Park, something scary lies in slumber. The steaming pools, bubbling mud pots and fountaining geysers testify to high temperatures not far below the surface – hardly surprising considering that the park is perched above one of the planet's biggest and most dangerous volcanoes. But only recently has the extent of the vast magma chamber below been revealed.

When seismic waves travel through the ground, they pass more slowly as they travel through fluids, such as magma. By using new data on the behaviour of seismic waves spawned by around 4,500 earthquakes, researchers have been able to build the clearest picture yet of the magma hidden within the crust at Yellowstone. It points to a reservoir two-and-a-half times larger than previously thought.

Worryingly, the chamber contains sufficient magma to put the biggest Yellowstone eruption of the past in the shade. Although no lava has erupted for 70,000 years, the new findings have concentrated the minds of both local residents and volcanologists on the threat lurking below.

Did you know?

The most recent super-eruption was 26,500 years ago

DID YOU KNOW? Yellowstone has up to 3,000 earthquakes each year

© Getty(Thinkstock)

High sulphur levels mean that some of the rock at Yellowstone is yellow

Yellowstone National Park has over 1,000 thermal features, such as boiling geysers

"It's important to note that Yellowstone's magma reservoir isn't getting any bigger"

Yellowstone is a supervolcano capable of eruptions that blast out more than 240 cubic miles of rock in one go – enough to bury a large city to a depth of several hundred metres. Super-eruptions are around 1,000 times larger than those of normal volcanoes.

As it stands, we don't know exactly how a super-eruption is initiated. Earthquakes or an injection of fresh molten rock into the magma chamber are both suggested triggers. But research published early in 2014 proposes that the pressure exerted by a growing magma body is capable of cracking open a route to the surface.

Super-eruptions are cataclysmic geological events that not only have the potential to cause regional obliteration of all life, but also wreak havoc on Earth's climate. Fortuitously, not all eruptions from a supervolcano qualify as super-eruptions – these shake the planet only a couple of times every 100,000 years or so. Their rarity is a measure of the small number of supervolcanoes – probably less than 100 out of a total of a few thousand active and potentially active volcanoes – and the fact that a special recipe needs to be followed if a super-eruption is to be conjured up.

Sticky, gas-rich magma known as 'rhyolite' is needed in huge volumes, retained in the crust in its molten state and then released all in one go. Places where the required conditions come together are few, but they are nicely met at the Yellowstone hotspot. Here, a rising finger of Earth's mantle melts to form basalt magma, which ponds at the base of the crust. This melts further to form a large body of molten rhyolite.

Over the past 2.1 million years, three titanic eruptions have ripped through the crust at Yellowstone. Each of these is marked today by a giant caldera – a cauldron-like crater in the ground – formed by post-eruption collapse. The most recent of the three eruptions formed the 43.5-mile-wide Yellowstone Caldera 640,000 years ago, in the process pumping out 1,000 times more ash than the 1980 Mount St Helens eruption in Washington in the Pacific Northwest. Since then, things have been relatively quiet.

Did you know?

Over 80 per cent of Earth's surface is of volcanic origin

This is not to say that the volcano is extinct, it's far from it. In the last 14,000 years alone, violent steam explosions have shattered the calm, leaving 20 large craters. Volcanologists also label the Yellowstone Caldera as 'restless' – it is constantly being shaken by small earthquakes, while the crust rises and subsides in response to the movement of heated groundwater and magma beneath.

DID YOU KNOW? A blast at Lake Taupō buried New Zealand in ash 18 centimetres deep

Hot springs such as this one are heated by Yellowstone's vast subterranean magma chamber

Inevitably, whenever this accelerates, speculation builds about the likelihood of a future eruption. The recent discovery that Yellowstone's magma reservoir is far bigger than previously thought has heightened such fears, but does it really make another super-eruption more likely?

The dimensions of the reservoir are stupendous – close to 56 miles long by 18.6 miles wide. The enclosed space should not, however, be thought of as a giant cavity filled with magma, but rather as a volume where between six and eight per cent of which is taken up by pockets of magma. This still works out at somewhere around 719 cubic miles of magma. If it all came out at once, it would be enough to dwarf the prehistoric blasts.

So should we all be thinking about loading up with a couple of years' supply of canned goods? Probably not. "There has been nothing mapped of that size before," says Dr Jamie Farrell, who led the research on the Yellowstone magma at the University of Utah. However, he adds: "It's important to note that the magma reservoir isn't getting any bigger."

In fact, the size of the reservoir has no direct bearing on when Yellowstone will next erupt, nor on the chance that the next blast will be a super-eruption. But past events do suggest that the average return period of these events is 700,000 to 800,000 years, which would mean another could be along any time soon – give or take 10,000 years. Dr Bob Smith, professor emeritus of geophysics at the University of Utah, makes the point that this estimate is based upon just two intervals, and begs the question: "How many people would buy something on the stock market on two days of data?" Even when the volcano does next erupt, overwhelmingly likely not in our lifetimes, the chances are that it will be a relatively tame affair.

MONITORING YELLOWSTONE USING THE LATEST TOOLS

SEISMOMETERS

These are a volcanologist's first choice of monitoring tool. A well-designed seismometer network can detect and track the swarms of earthquakes generated by magma breaking up rock on its way to the surface. An acceleration in the rate of earthquake activity can be used to predict the timing of a forthcoming eruption.

GLOBAL POSITIONING SYSTEMS

GPS is used to monitor the swelling of the surface that typically precedes an eruption. Vertical and horizontal movements as small as a few centimetres can be detected, building a pattern of surface deformation that can provide information on the location and depth of the magma body below, along with its shape and size.

GAS ANALYSES

Analysing the gases emitted by a volcano can provide useful warnings. An increase in the amount of sulphur dioxide is usually a sign that magma is coming closer to the surface, while the detection of gases such as radon and helium may also herald an eruption.

SATELLITES

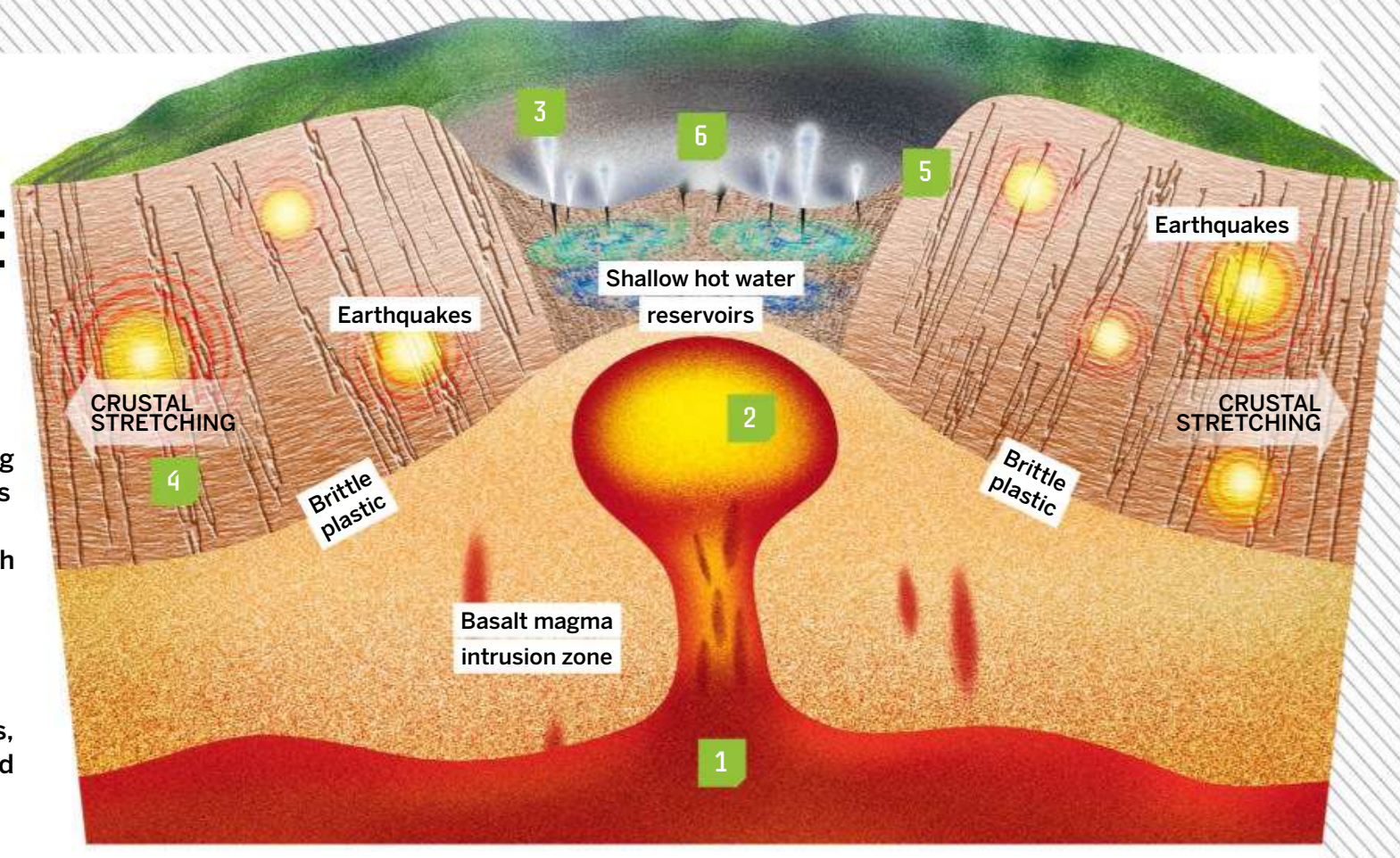
Satellite observation plays an increasingly important role in volcano monitoring, particularly in difficult-to-access spots. Large-scale surface deformation can be detected using radar interferometry techniques, while thermal imaging can trace lava flow fields.

© Getty (Thinkstock) / NASA

SLICING OPEN YELLOWSTONE

The mass of magma in this supervolcano is shifting the ground

Deep beneath Yellowstone, hot basalt magma generated by the melting of a rising finger of Earth's mantle heats up and melts the granite rock that forms the overlying crust. The resulting mass of sticky, gas-rich rhyolite magma accumulates in a giant reservoir, from which it's periodically released to the surface. It's this rhyolite that feeds super-eruptions and smaller outpourings of magma. Between eruptions, the subterranean movement of magma and heated groundwater promotes ground swelling and clusters of earthquakes.



1 MAGMA
Hot basalt magma rising from the planet's underlying mantle melts the crust.

2 RESERVOIR
The Yellowstone magma reservoir contains large amounts of sticky rhyolite magma.

3 GEYSERS
Geysers and boiling springs are driven by the intense heat from the magma close beneath.

4 CRUSTAL STRETCHING
Rising magma causes the neighbouring crust to become deformed.

5 GEOLOGICAL FAULTS
These define the edges of the collapsed caldera.

6 DOMES
These mark the sites where lava escaped during some of the most recent eruptive activity.

Lake Toba in Sumatra, Indonesia, was the location of one of the most recent supervolcano eruptions, 74,000 years ago

If the doom-mongers are right, however, and the Yellowstone magma chamber does disgorge a substantial fraction of its magma, then the consequences will be appalling. The blast 640,000 years ago sent blistering flows of scalding ash and gas hurtling across what is now Wyoming and neighbouring states, with ash falling as far afield as modern-day Texas and California. A repeat performance today would paralyse the US economy and devastate its agriculture. In fact, the ensuing impact on the world's climate could be apocalyptic, and might even be capable of bringing global society to its knees. Following the second-latest super-eruption at Lake Toba in Sumatra, which occurred around 74,000 years ago, a severe 'volcanic winter' triggered by the cooling effect of a worldwide veil of sulphur gases in the stratosphere resulted in snow and ice expanding to cover around a third of the planet.

Some volcanologists and anthropologists have even argued that the freezing aftermath could have brought the human race close to extinction. With around 8 billion of us living on the planet today, we're probably insulated from total annihilation of the human race, although the complete failure of global harvests for several years would likely result in a severe decline in the planet's population.

While we can't be absolutely sure that Yellowstone will ever again produce a super-eruption, we can be certain that sometime in the future, somewhere in the world, there will be another, and there's absolutely nothing we can do to stop it.

Drilling into a bulging supervolcano to allow it to 'let off steam' would have next to no effect. What we should be doing is watching and planning. Unfortunately, of the world's 1,500 or more active volcanoes, only a couple of hundred are currently adequately monitored. As a result, a supervolcano could be building to eruption in the remote Andes or the jungles of Indonesia, and we might not know about it until it's too late.

Although it's hardly surprising given that a volcanic catastrophe happens on average every 50,000 years, no government has given a moment's thought to how it might ensure the survival of its people during the global freeze and inevitable harvest failure that will follow the next super-eruption. Perhaps it might be a good idea to start hoarding those tins of food after all - just in case.

Did you know?

Bolivia's Uturuncu volcano has been swelling since 1992

© NASA / illustration: Andy Mclaughlin

DID YOU KNOW? Pearls are the only gems made by living creatures

HOW OYSTERS MAKE PEARLS

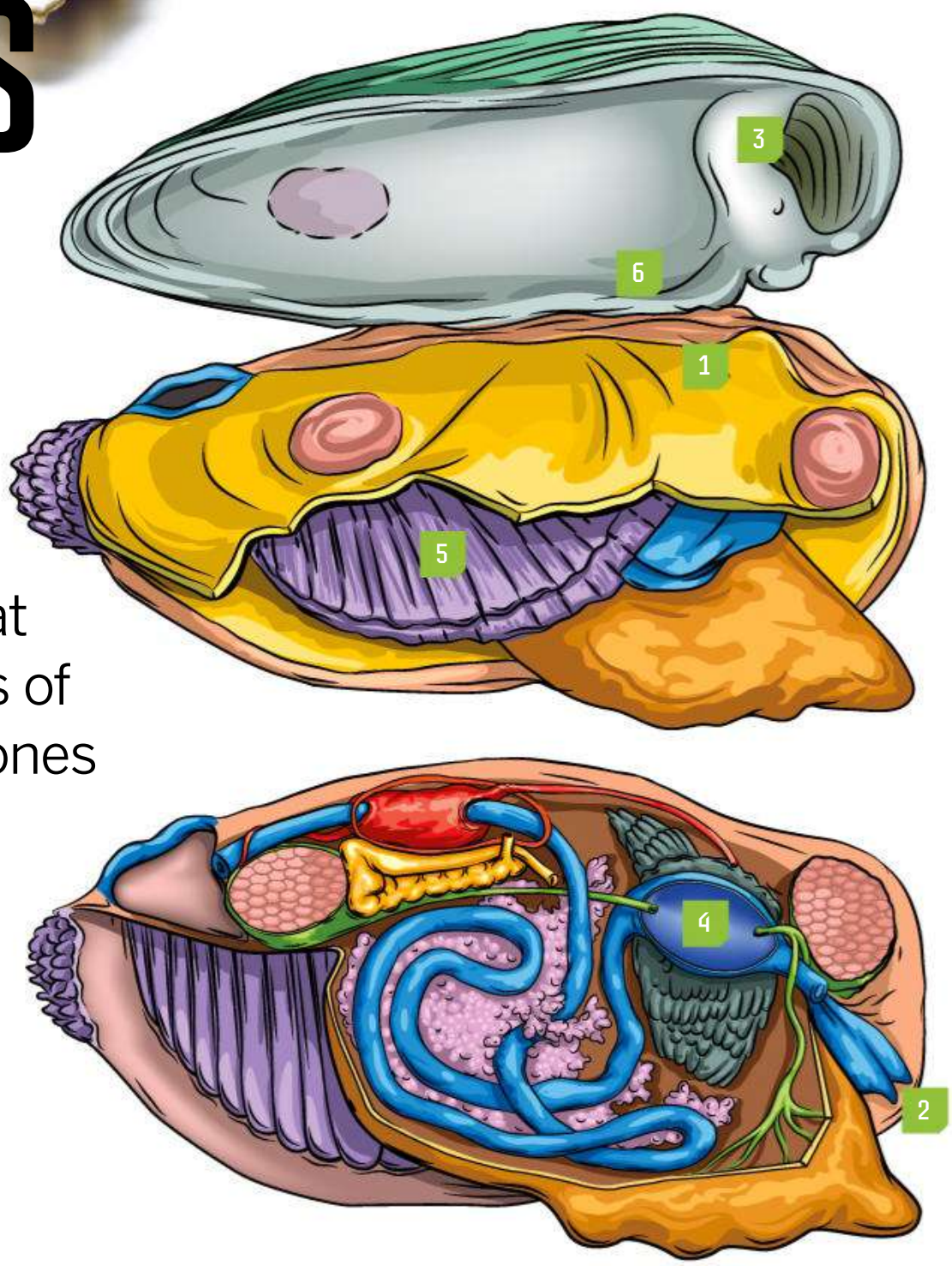
Meet the jewellery-making molluscs that turn irritating specks of dirt into stunning stones

WORDS **AILSA HARVEY**

Pearls are smooth, shiny gems that are commonly seen on a long string decorating elegant necks. They have been used as a fashion accessory since at least the 5th century BCE by the ancient Romans and Egyptians. But the process that creates these mesmerising gems isn't geological – they're made by slow-moving marine and freshwater animals as a kind of symbol of their suffering. Molluscs such as oysters, mussels and clams produce pearls as a byproduct of defence. They are made when these aquatic creatures attempt to rid their bodies of parasites, sharp pieces of shell matter or other debris that gets trapped inside their shells when they open them to feed. They secrete calcium carbonate, which is the core material that makes up a mollusc's shell, in a crystallised form when a irritant is present. It's called aragonite, and combines with protein fibres to coat smooth layers around the foreign object. The result is a creamy-coloured solid ball that serves as a barrier between the object and the soft internal tissue of the mollusc. Today, most pearls aren't harvested naturally. Instead, humans place a suitable irritant into an oyster to trigger this response and increase pearl production rates.

INSIDE THE SHELL

Oyster anatomy and the pearl-making process



1 MANTLE
This fleshy inner lining produces calcium carbonate crystals called nacre.

2 MOUTH
When food is near, oysters open their shells to expose their mouths. This is when debris such as broken shells can enter, irritating the soft internal tissue.

3 OUTER SHELL
The tough outer shell is made of the calcium carbonate produced by the mantle. It's arranged in a strong lattice to cover the oyster's soft internal tissue.

4 STOMACH
Oysters eat a lot of algae as part of their diet. This is rich in calcium, which they digest and use to make up their shell and pearls.

5 GILLS
Water flows into the oyster through the gills, as beneficial nutrients are filtered into the body.

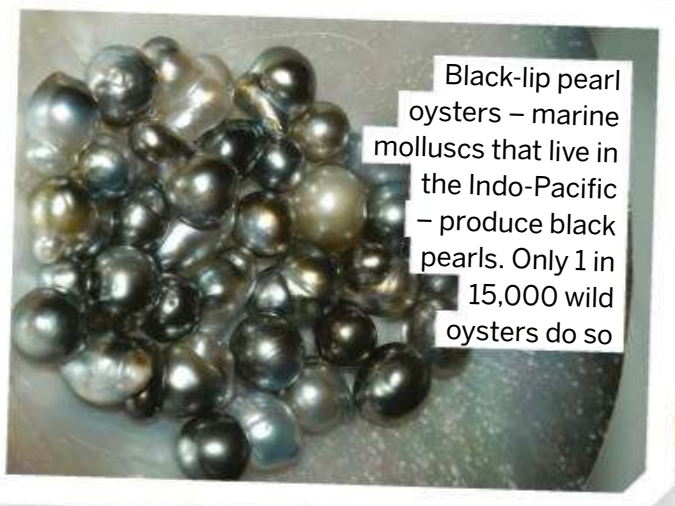
6 PEARL DEPOSIT
Cells in the mantle excrete extra nacre when an irritant enters the oyster. The irritant then develops a covering, forming a pearl between the shell and the mantle.

SALTWATER OR FRESHWATER

There are a few structural and biological differences between saltwater and freshwater pearls and the oysters that make them. Colour is one of the main differences, which is determined by the composition of the oysters' mantles and the nutrients available in their environment. Pearls can be white, cream, yellow, blue or black with a translucent coating.

Pearls produced in warm southern sea waters are usually light in colour, being white, cream or golden. Meanwhile, freshwater pearls generally hold a broader spectrum of colour. This can include pink, orange, purple and green tinges. This is due to trace amounts of minerals and metals, such as copper, which creates shades of green.

Saltwater pearls are generally more expensive than freshwater pearls as they are rarer and more difficult to farm. One freshwater oyster can produce over 100 pearls, but saltwater oysters generally only make one pearl in their entire lifetime.



Black-lip pearl oysters – marine molluscs that live in the Indo-Pacific – produce black pearls. Only 1 in 15,000 wild oysters do so

© Alamy / Shutterstock

HOW ANIMATION WAS INVENTED

Before cinema, moving images were created using clever visual illusions

WORDS **NIKOLE ROBINSON**

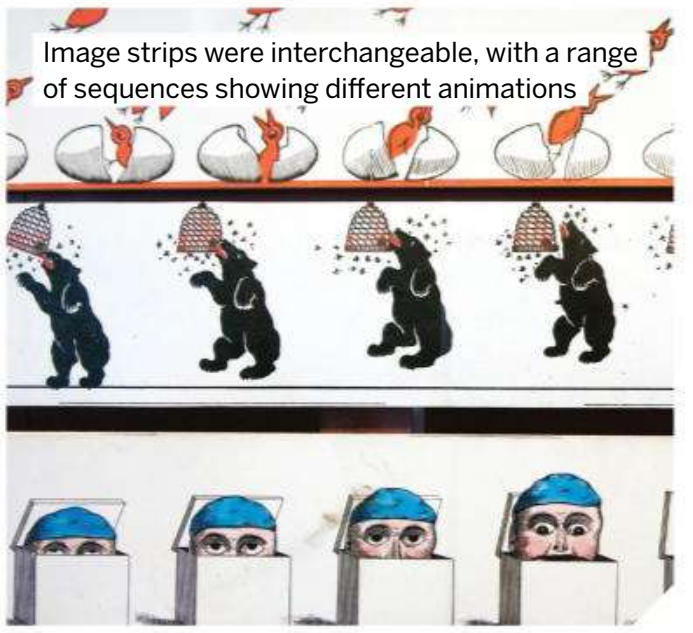


Image strips were interchangeable, with a range of sequences showing different animations

While much of the animation that reaches our screens today is generated on computers, the history of hand-drawn animation goes back almost two centuries. Creating the illusion of movement was first achieved using a sequence of images on a flat disc called a phenakistoscope. Evenly spaced along the circumference of the disc were viewing slits, looked through as the user held the device up to a mirror and spun it. Peering through these slits at the images reflected in the mirror created a seamless looping sequence while the disc rotated at the right speed.

Several experimental contraptions were inspired by the phenakistoscope in an attempt to create a similar visual trickery, but the zoetrope was by far the most successful. Designed by William Ensign Lincoln in 1865, the zoetrope was a hollow drum perched atop a spindle, within which a strip of incrementally changing images could be placed. Vertical viewing windows were spaced around the zoetrope in order to view the strip of pictures inside. These were cut out higher on Lincoln's version than in similar patents, above the image strip itself, allowing the strip to be replaced with others easily. With each stage of the strip lined up opposite these apertures, spinning the device brought the succession of still images to life for observers – and unlike the phenakistoscope, multiple people could view the animation at once.

Lincoln sent his design to board game manufacturer Milton Bradley Company, who by Christmas 1886 had advertised it as an exciting optical toy. The mass-produced version featured 13 slots around the drum to ensure that the animated sequences would run smoothly. The zoetrope proved a popular form of entertainment, and by 1868 there were 73 different strips available for the device.

Did you know?

Sony built the largest zoetrope, at 9.9 metres in diameter

The zoetrope became a popular toy for children

Images had to be bold, since any small details blurred out when the device was spun, and usually only featured a few bright colours.

Going back to the phenakistoscope's utilisation of reflection, the praxinoscope of 1877 improved on the zoetrope by replacing the thin viewing slots with a central circle of mirrors, resulting in better stabilisation and a brighter image with less distortion. Its inventor Émile Reynaud would develop a version that could project animated sequences in 1888, but this was soon superseded by photographic film projectors and the dawn of cinema.

FLIPPING THROUGH STILL IMAGES

Also known as a kineograph, a flipbook is a simple form of animation still enjoyed today. Each stage of an animation is drawn on a separate piece of paper, together forming a small booklet. When the pages are flipped through in quick succession, the images on each page blend to create a moving picture. Though these are of much simpler design than the zoetrope and similar devices, the first documentation of a flipbook wasn't until 18 March 1868, when zoetropes were already widely available.

Flipping through the pages brings the images to life

DID YOU KNOW? The Ghibli museum in Tokyo features a 3D zoetrope based on the film *My Neighbor Totoro*

INTO ANOTHER DIMENSION

The first 3D zoetrope was built in 1887 by Étienne-Jules Marey, featuring models of a bird in flight and viewed through slits in the same way as a traditional zoetrope. But modern developments have allowed artists to ditch the drum entirely. Animator Eric Dyer designs rotating sculptures that follow the same principles. Kevin Holmes uses a combination of 3D printing and strobe lighting to create hand-painted carousels that spring into action when revolving at the right speed.

3D printing is used in some modern zoetrope designs

SLITS AND MIRRORS

How the zoetrope and its successor made pictures move

8 IMPROVED VIEWING
Due to the open design, the images appeared brighter. Some praxinoscopes even had lamps fixed above them.

1 VIEWING SLIT
These would be looked through as the device was spun, allowing more than one person to see the motion.

2 IMAGE STRIP
Easily switched out with other designs, strips with various series of images were placed inside the zoetrope to create different effects.

7 RING OF IMAGES
Much like its predecessor, the praxinoscope had a band of images on the inner side of the drum.

5 INNER MIRRORS
Reflective mirrors sat about halfway between the centre and the outer rim of the praxinoscope.

6 HAND CRANK
Rather than simply spinning the device, a crank could be turned. Later versions were powered by electricity.

3 FLOOR DESIGN
Some also had patterns on the base, though many mass-produced zoetropes didn't have this feature.

4 SPINNING AROUND
The cylinder sat atop a spindle, creating a mechanism that could easily be spun by hand.

SETTING IN MOTION

1825
The thaumatrope was introduced, where two images on either side of a small disc appear as one when spun between two strings.

1832
Belgian physicist Joseph Plateau and Austrian inventor Simon Stampfer both independently created the phenakistoscope.

1834
William George Horner theorised a cylindrical version of the phenakistoscope, which he called the dædaleum, but it was never produced.

1855
Johann Nepomuk Czermak proposed the stereophoroskop, which used both slots and a central mirror to display movement.

1860
Peter Hubert Desvignes patented his mimoscope, a stereoscopic drum spun on a horizontal axis. He used this to show the motion of animals in 1862.

1865
Lincoln invented the zoetrope. Its name came from the Greek for 'life', zoe, and tropos, meaning turn'.

1868
James Clerk Maxwell constructed an advanced version of the zoetrope that used concave lenses in place of slits.

1877
French inventor Charles-Émile Reynaud created the praxinoscope, which used central mirrors to reflect a strip of images.

© Alamy / Getty / Illustration by Adrian Mann

THE ORIGINS OF WEIGHTS AND MEASURES

Left: An illustration of a standard metre hanging in the Petit Luxembourg, Paris, in 1799, following the end of the French Revolution

Below: The Anglo-Saxons used three barleycorns to measure an inch

Why did much of the world switch from the imperial to the metric system?

WORDS **SCOTT DUTFIELD**

Since civilisation began, humans have created ways to measure and standardise units of measurement for things. Typically for trade and agriculture, early measures in Mesopotamia – what is mostly Iraq today – utilised parts of the human body, seeds and stones to create standards of measure. Up until 1700 BCE, the people of the Harappan civilisation in Punjab, India, created intricate weighing scales and developed measurements such as the 'Indus inch', which is equal to 1.32 inches. Ten of these equalled a 'foot', although it's unclear whether or not the Harappa people had such big feet.

The first standardised system of units is believed to have originated in Great Britain and is known as the imperial system. However, this collection of units of measurement evolved from thousands of years of Roman and Anglo-Saxon influence – that is, ancient Italy and ancient England. For example, the Anglo-Saxons used a unit of length known as a barleycorn, which has now been standardised to 8.5 millimetres, that's still in use today to measure shoe size. The imperial system was formally standardised and adopted when the Weights and Measures Act of 1824 came into force. New measurements such as the imperial gallon became the norm, which is equal to ten pounds (around 4.5 kilograms) of water at 62 degrees Fahrenheit (16.7 degrees Celsius).

Over time, the world's measurements rapidly evolved, and more and more names for different weights and measures emerged. By the 18th century, it was estimated that there were more than 800 different units of measurement for traders and farmers to contend with around the world. That was the case until a new standardised system emerged, sweeping the world.

Did you know?

1,000 Roman paces is equal to a mile

The metric system, also known as the International System of Units, originated in France during the French Revolution, which ended in 1799. Ditching the imperial standard, French scientists and mathematicians developed a new decimal-based system that operated in multiples of ten. Taking inspiration from nature, the novel 'metre' was defined as one ten-millionth of the distance from the North Pole to the equator.

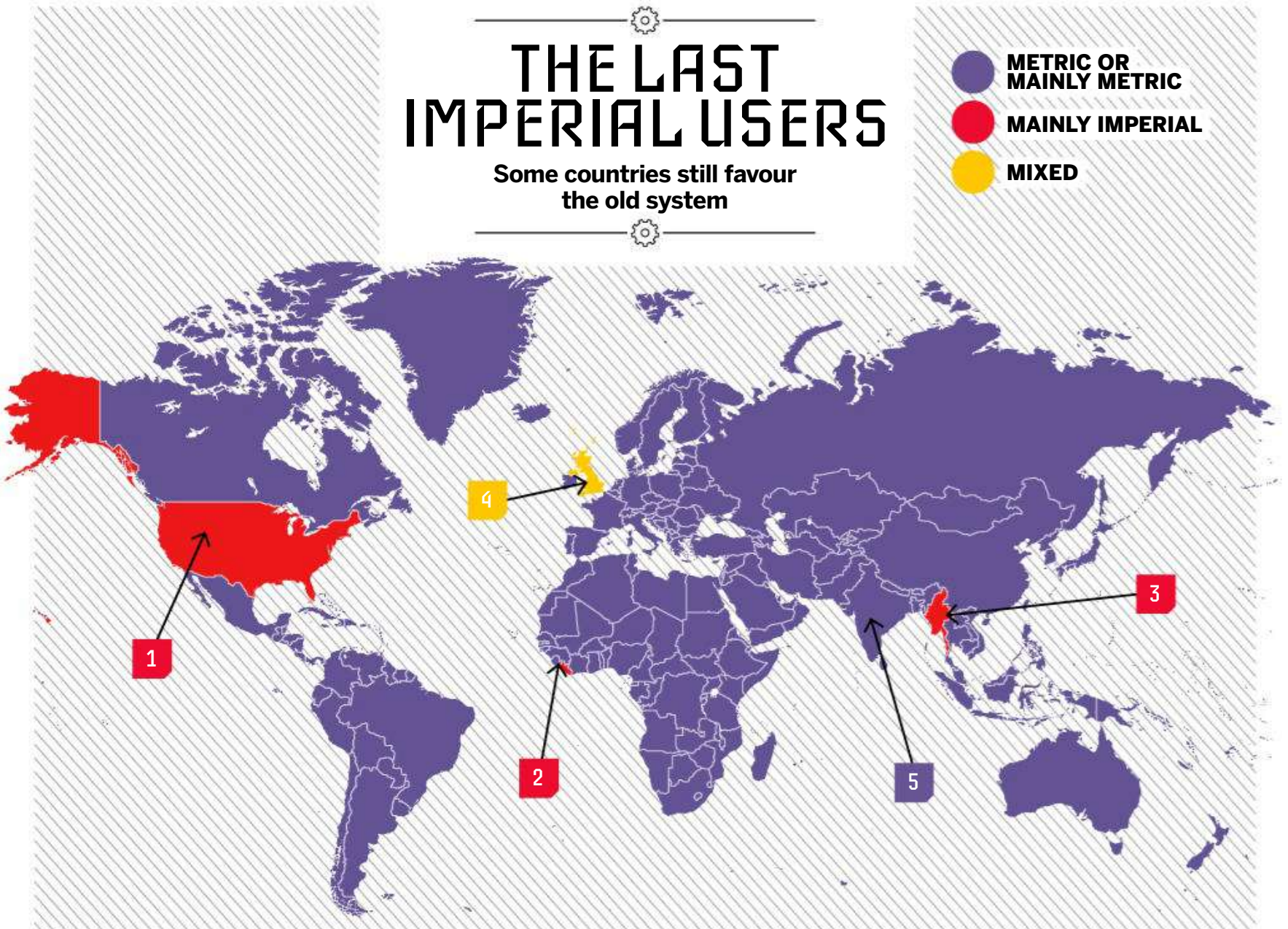
The new system wasn't an immediate success, and in 1812 was abolished by Napoleon, allowing people to use whichever method they wanted before France reinstated the metric system in 1840. For more than 200 years the metric system has been used by the majority of the world's countries, and its units have become universally used in engineering and manufacturing.

A collection of cubit measuring rods used in Egypt around 1550 to 1292 BCE

DID YOU KNOW? More than eight in ten Britons still use imperial measurements day to day

THE LAST IMPERIAL USERS

Some countries still favour the old system



1 US
Despite the metric system being declared lawful in the United States in 1866 and Congress voting it to be the preferred system of weights and measures, the majority of the American population still use the imperial system.

2 LIBERIA
As a former colony of the United States, this West African country inherited the imperial system. However, it's been reported that the country is looking to officially make the change to the metric system.

3 MYANMAR
This Southeast Asian country largely uses a combination of the imperial system, such as miles and gallons, and its own units of measure, such as 'viss' for weight, where one viss is equal to 1.68 kilograms.

4 UNITED KINGDOM
Unable to completely convert, many Britons still use imperial measurements today, such as 'stone' to measure weight and 'feet' for height, despite the government beginning a move towards metrication in 1965.

5 REST OF THE WORLD
By the mid-1970s the majority of the world had ditched imperial measurements and adopted the metric system.

THE EGYPTIAN CUBIT

Around 3000 BCE, ancient Egyptians developed one of the earliest known units of measure, called a cubit. Used as a unit of length, a cubit was equal to the length from the elbow to the fingertip. To standardise the length, a royal cubit rod made from black granite was created to use like a metre stick, equal to 45.7 centimetres. For smaller measurements, the royal cubit was broken down into the width of a finger, known as a digit. One cubit equalled 28 digits, four digits equated to a 'palm' and five digits to a 'hand'. Over time the cubit measuring system expanded to include 'large spans' (half a cubit) and 'small spans' (three palms) and reached new civilisations, with the Babylonian cubit emerging around 1700 BCE.

5 WEIRD MEASUREMENTS THAT ARE STILL IN USE

1 FURLONG
Used to measure the distance ran by a racehorse, one furlong is equal to 201.168 metres. Its origins come from the length of ploughed furrow that could be created by an ox without rest.

2 LEAGUE
Still used in several countries but brought to England by the Normans, a league is equal to the length a person can walk in an hour, which they estimated was around three miles.

3 KLICK
A klick is another way of saying a kilometre in the military. It's believed that its origin comes from the clicking sound made by rifle gas regulators when they were reset after 1,000 metres of trekking

4 ROD
Derived from the old English word 'rodd', meaning stick of wood, this agricultural unit of measurement is typically used to describe allotment sizes and equals 5.029 metres.

5 NAUTICAL MILE
Unlike a typical mile, this seafaring alternative is equal to one minute of travelling along Earth's latitude either side of the equator, or 1,852 metres.

© Alamy / Getty

AMAZING FUTURE SPACE ROBOTS

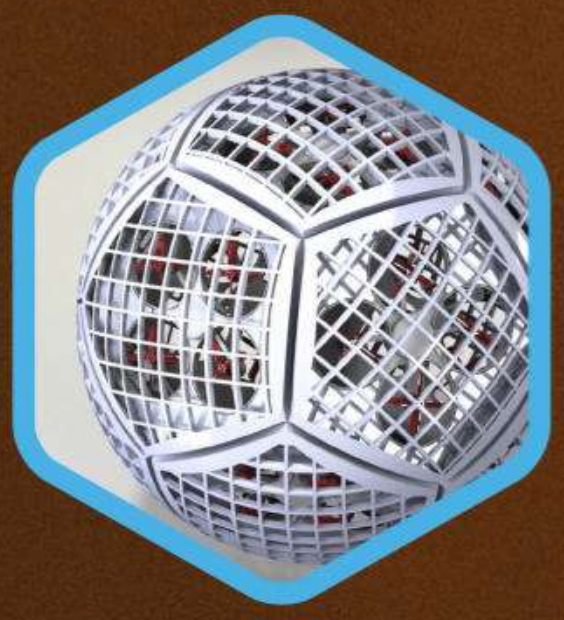
WORDS
AILSA
HARVEY

Discover the versatile space machines that can roll, fly, float and swim, from junk recyclers to station companions

Humans have been sending things into space since 1957. The technology behind space travel is considered to be one of humanity's most impressive engineering feats. By sending robotic probes and astronauts safely beyond Earth's atmosphere, scientists have been able to make incredible discoveries and heighten our knowledge of the universe. However, the deeper into space we explore, the further we step into the unknown and the riskier human space exploration becomes.

To help mitigate these risks, there has been a surge in the production of space robots, and these are becoming increasingly advanced. It's estimated that by 2030, the space robotics market will reach a value of £5.7 billion ($7.3 billion). Materials with a high tolerance for space's extreme radiation and temperature levels are used in space robotics production, and the results are often lighter and cheaper to launch than astronauts. Although human astronauts will always be required to relay reliable information about how space environments impact human life, space robotics give scientists the opportunity to delve into the harshest environments and extend the boundaries of space exploration safely.

DID YOU KNOW? OSAM-1 will be the first mission to refuel a satellite that wasn't designed to be serviced

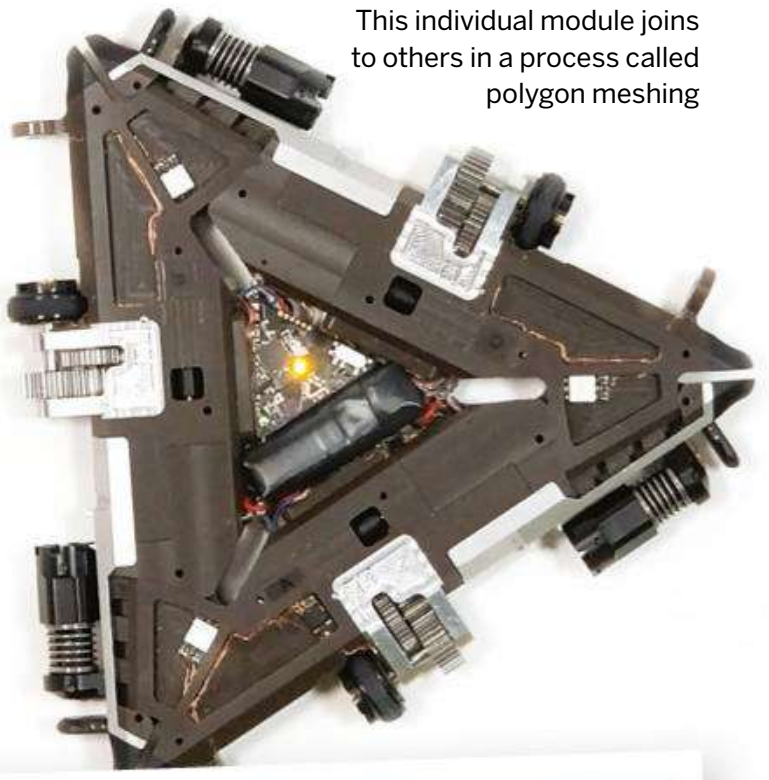


MORPHING MACHINE

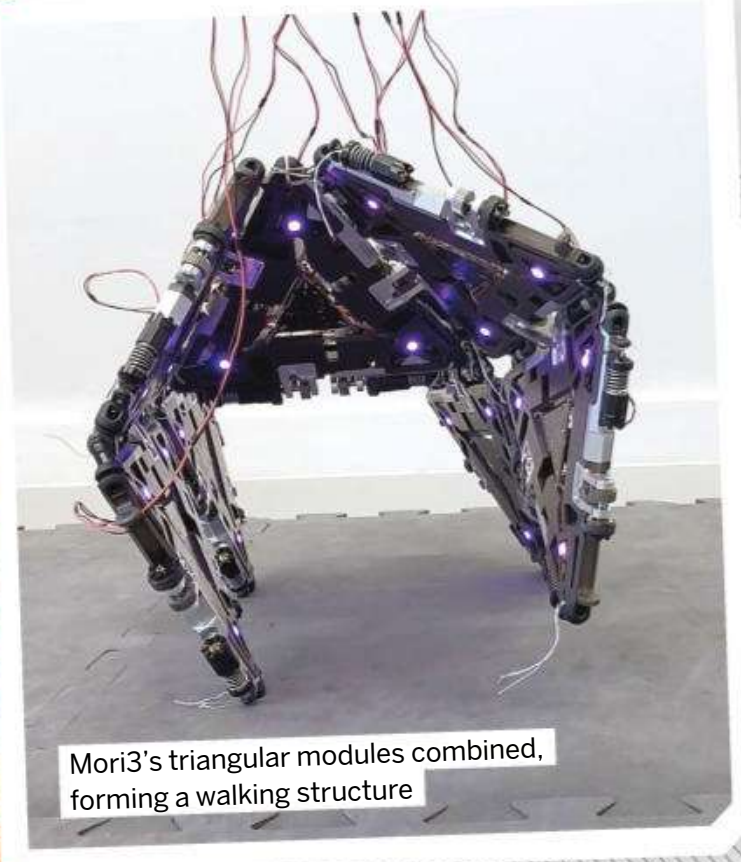
One shapeshifting robot can adapt quickly to traverse across landscapes, carry cargo and make repairs on spacecraft: the European Space Agency's (ESA) Mori3. Mori3 is a modular robot inspired by origami. Consisting of a series of triangular panels, the sides of each module can connect to form almost any 3D shape. The production of Mori3 is still in progress, but in the near future its creators at the Swiss Federal Institute of Technology Lausanne are focusing on the possibility of the shapeshifter to assist on spacecraft. The benefits of taking Mori3 to locations such as Mars include space-saving and flexibility. The robot can be stored flat and vertically, ready to perform multiple roles and adapt to both the known and unforeseen challenges of space exploration.

Did you know?

Mori3 is being designed for the first manned Mars mission

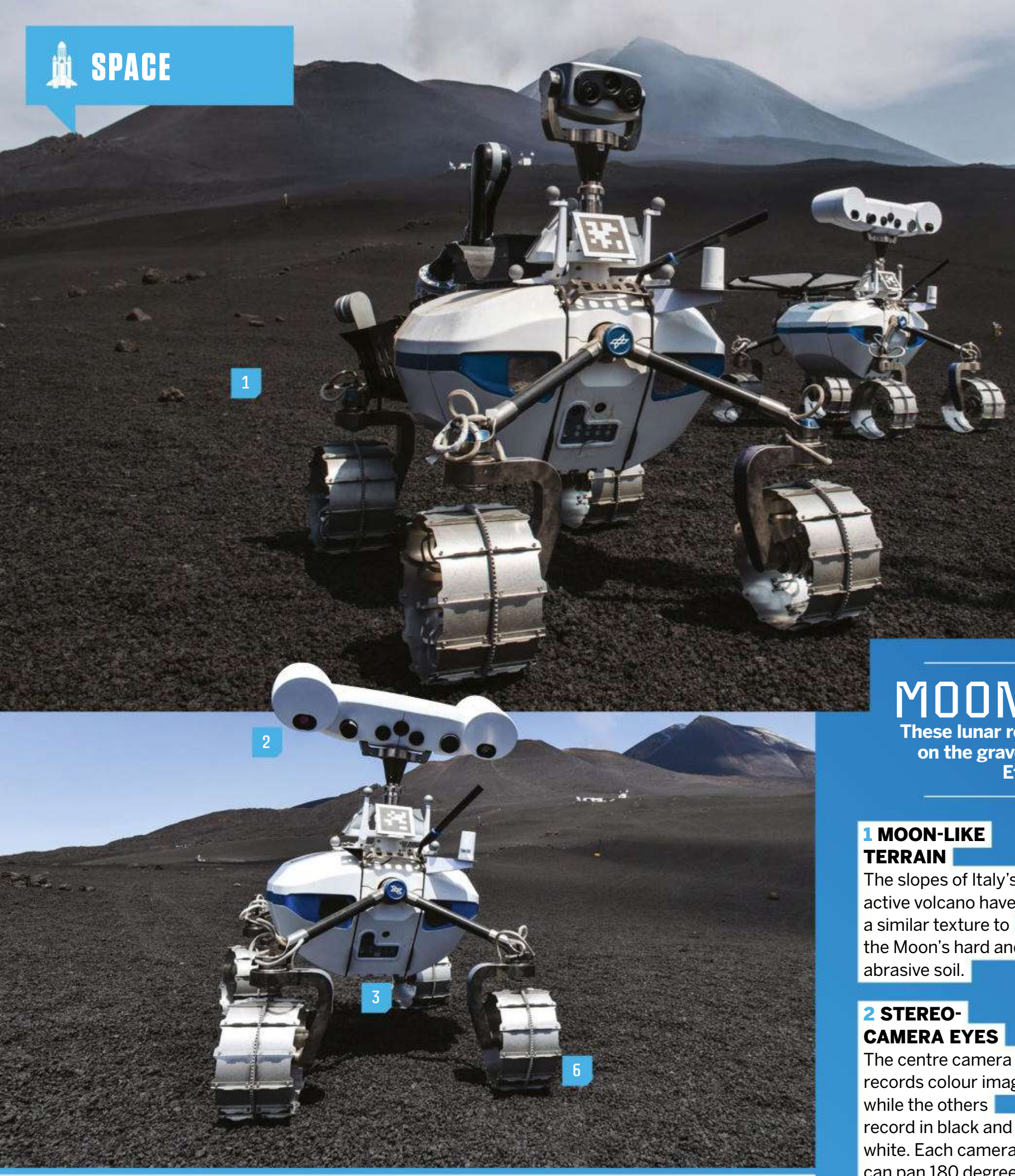


This individual module joins to others in a process called polygon meshing



Mori3's triangular modules combined, forming a walking structure

© Getty / EPFL RRL / NASA:JPL / CNSA



Did you know?

Over 250 robotic spacecraft have been launched into space

MOON ROVERS

These lunar robots are being tested on the gravelly terrain of Mount Etna in Italy

1 MOON-LIKE TERRAIN
The slopes of Italy's active volcano have a similar texture to the Moon's hard and abrasive soil.

2 STEREO-CAMERA EYES
The centre camera records colour images, while the others record in black and white. Each camera can pan 180 degrees and tilt 90 degrees.

3 LRU1
Lightweight Rover Unit 1 has the main task of mapping the terrain it covers with its cameras.

4 LRU2
Lightweight Rover Unit 2 is the sibling of LRU1. This rover can analyse loose objects on the Moon.

5 ROBOTIC ARM
This extendable arm can pick up baseball-sized rocks and record tactile feedback. This means scientists can feel the lunar objects by using a special glove on Earth.

6 LUNAR WHEELS
Each wheel on the rovers can be individually steered to navigate tricky terrain.

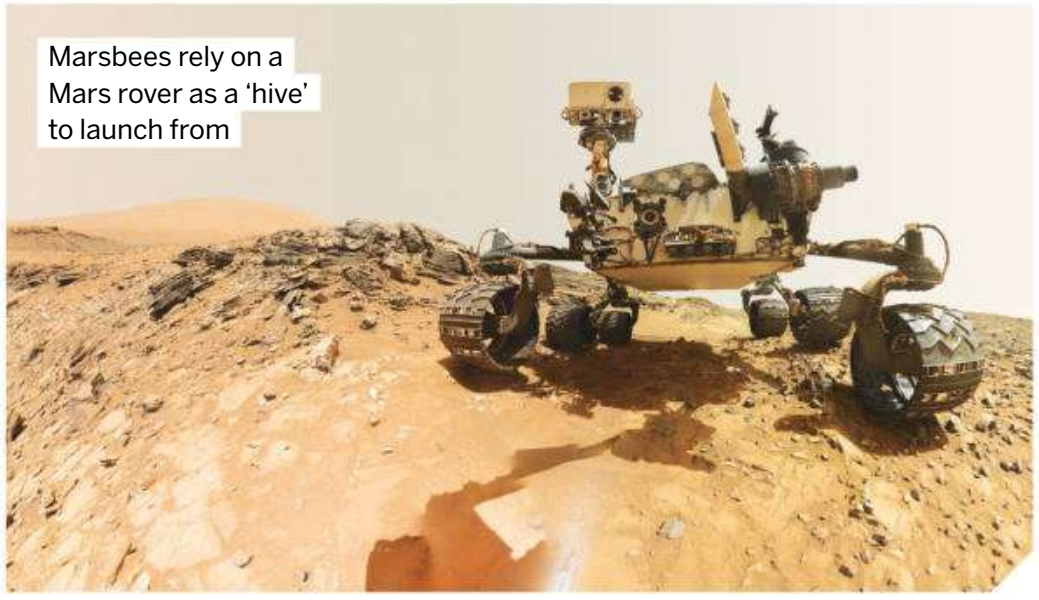
7 CAMERAS AND SENSORS
LRU2 navigates using cameras and sensors, determining chemical compositions of Moon samples by shining a laser beam onto any rocks it has collected.

8 IMU
The rovers' inertial measurement units measure the angle of movement and velocity and acceleration of travel to balance the rover, keep a record of its position and accurately map distances.

DID YOU KNOW? During the LRU rover test at Mount Etna, ex-astronaut Thomas Reiter controlled a robot from 14 miles away

SWARMING ROBOTS

Examining the surface area of a new planet can be a daunting task for a single rover. Although modern rovers are technically advanced and are built to carry all the necessary tools to dig, collect and examine soil samples, one rover can only cover so much ground in its lifetime. A different technique that has captivated the imaginations of space robot engineers is swarm technology. Working together like bees in a colony, small and simple flying robots could be sent to swarm through a new planet's atmosphere and record conditions using their cameras, sensors and wireless communication devices. NASA previously tested this idea using bee-sized robots called Marsbees. Designed to flap like the wings of bees, these robots are engineered to connect to a Mars robot base. When the Marsbees are launched, they communicate with each other and the base robot, which sends them in different directions within a 1.5-mile radius. The concept of swarm robots has opened up new possibilities for near-future exploration missions.



Marsbees rely on a Mars rover as a 'hive' to launch from

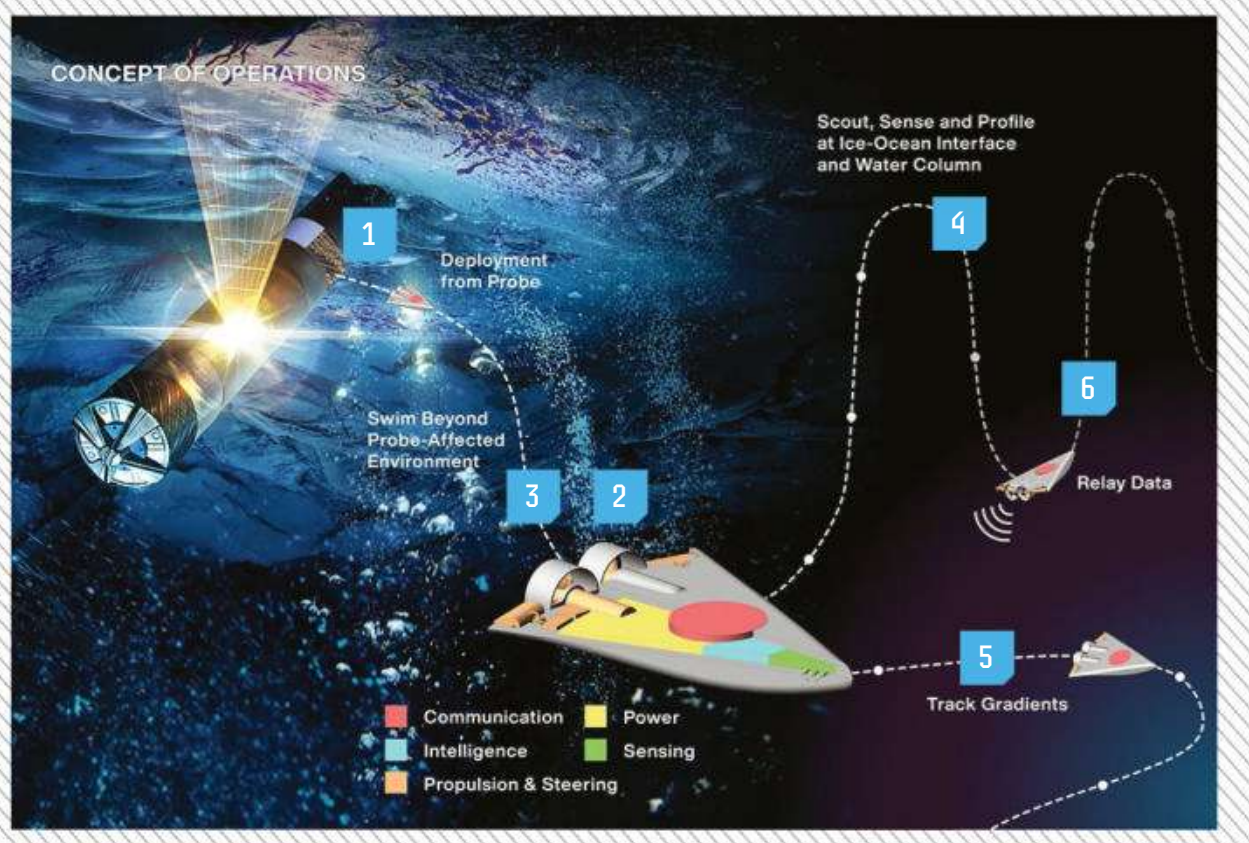
SCANNING SATURN'S MOONS

Following testing at NASA's Jet Propulsion Laboratory, the Shapeshifter robot may be tested on Saturn's moons as soon as 2026. As it analyses locations on the moons – where some of the only surface liquid in space has been detected in the form of methane lakes – the robot can roll, fly, float and swim. In order to carry out so many motions, the robot will need to change form. In its standard mode, the robot is a single modular vehicle. However, when at a unique site that needs to be explored in depth, the robot can transform. The system consists of multiple smaller units called cobots. These cobots are simple, slightly rounded structures that look like the pentagonal segments of a football. Depending on the topography, these cobots can combine to form a rolling ball, a flat hovering drone or a self-propelled swimming machine.

NASA is testing Shapeshifter in the form of 3D-printed prototypes

NASA'S SWIMMING ROBOT CONCEPT

How microswimmer robots could explore the seas beneath the icy shells of frozen moons



1 ICE-MELTING PROBE
A lander drills this probe into the ice on Saturn or Jupiter's moons. Heat from the probe's nuclear battery melts a route through to the water below.

2 SWIMMER ROBOT
Each self-propelled robot is about 12 centimetres long. They have instruments to record and communicate temperature, salinity, pressure, composition and acidity.

3 ROBOT RELEASE
50 Sensing With Independent Micro-swimmer (SWIM) robots are released from the probe after it has melted through the ice.

4 EXPLORATION
The robots explore in multiple directions, far enough away from the probe that the heat of their entry doesn't affect recordings.

5 SENSOR COMPARISON
The collective data from the sensors at the front of each robot can display any salinity, temperature or chemical gradients across the area searched.

6 COMMUNICATION
Each robot has an ultrasound communication system and relays its data back to the lunar lander above the ice. This collected data is sent to scientists on Earth.

© DLR (CC BY-NC-ND 3.0) / DLR/Esther Horvath / NASA/JPL-Caltech/MSSS

SATELLITE SERVICER

Like all technology on Earth, machines sent into space have a limited life span. When they cease to work or complete their mission, many end up in orbit for many years, while others fall out of orbit and burn up in the atmosphere. But what if there was a way to restore the abilities of old satellites in space? NASA's On-orbit Servicing, Assembly and Manufacturing (OSAM) is a robotic spacecraft that can mend satellites. The robot can attach to satellites, manipulate them with its robotic arms, refuel and move them, including those which weren't built with this service in mind. The launch of OSAM-1 is due in 2025 and is set to reduce the limitations of satellites. By keeping them in space for longer, increasing communication and data collection will become more efficient and aid further space exploration.

The two silver spheres in this image of OSAM contain fuel for satellites

FLOATING HUMANOID ASSISTANCE

Taikobot is a new robot built to assist astronauts on the Chinese space station Tiangong. Despite being as tall as an average adult, Taikobot has the weight of a small child and can use its hands to grip tools such as hammers and electric screwdrivers, as well as move packages. Unlike humanoid robots on Earth, Taikobot can navigate the weightless environment of space by pushing off from surfaces, taking flight and parking up by attaching to hand rails or foot restraints on the space station. Its sensors can detect other movement in the space station and automatically adjust its path in mid-air to avoid collisions with other astronauts. Alongside manual tasks, Taikobot's advanced sensors can monitor the health of its human astronaut companions, such as recording their blood oxygen saturation levels. Although a human presence on space stations is essential, assistance from a humanoid robot can increase efficiency. After all, robots don't need the same sleep, food or bathroom facilities as people.

Taikobot weighs 25 kilograms

SPACE RECYCLING

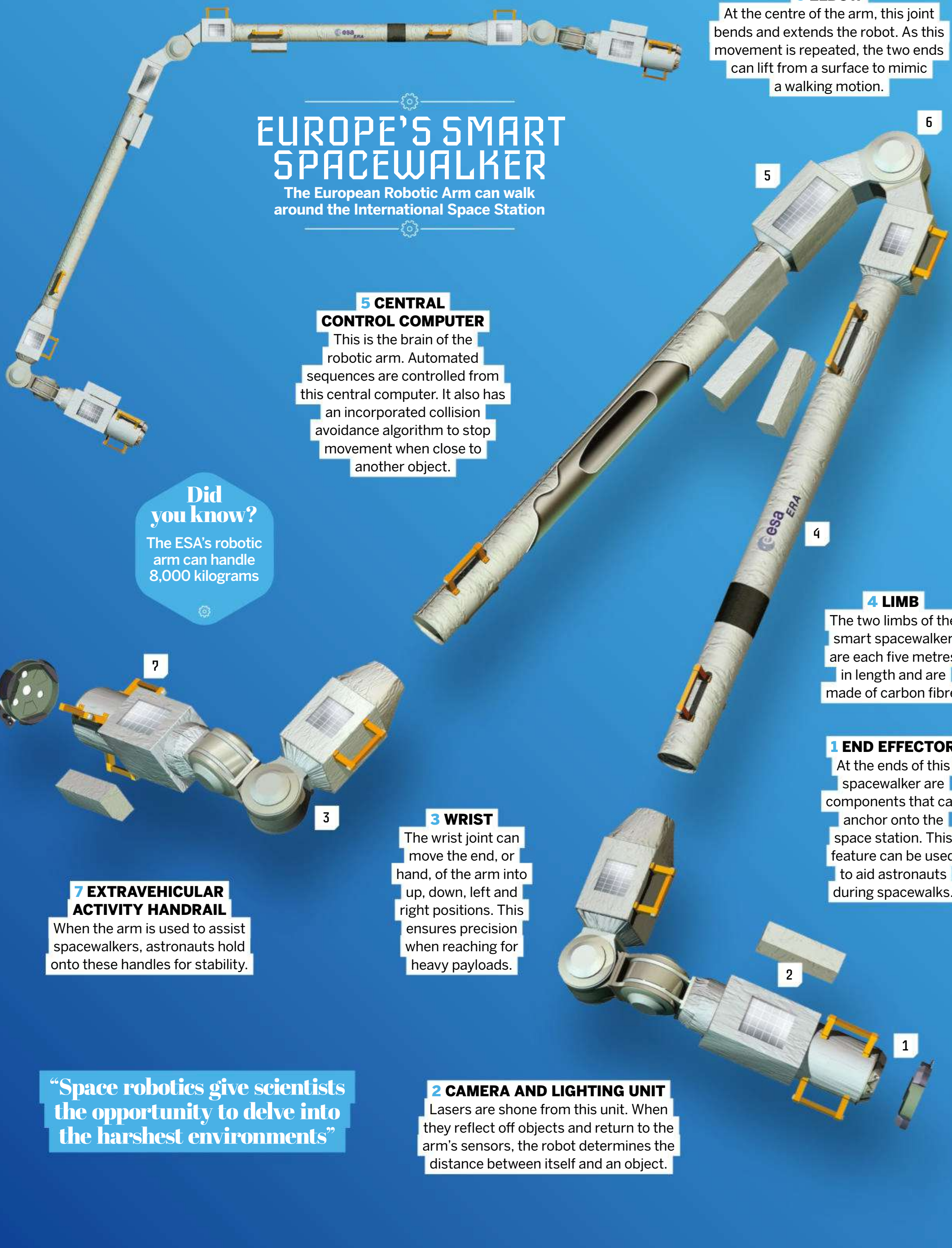
In the future, self-propagating robots could transform how technology is built in space. Instead of sending supplies from Earth into space, robots could attach themselves to orbiting space junk and repurpose the materials they grab hold of. Future colonies on the Moon or Mars won't be able to rely solely on supplies from Earth, so engineers aren't just uncovering ways to utilise natural resources, but also methods of repurposing obsolete and abandoned technologies from previous space missions. Companies such as Lockheed Martin are working to make these robots a reality by 2050.

There are an estimated 200,000 pieces of space junk between one and ten centimetres in size

DID YOU KNOW? By ‘flocking’ like fish, SWIM robots can reduce errors in data

EUROPE’S SMART SPACEWALKER

The European Robotic Arm can walk around the International Space Station



5 CENTRAL CONTROL COMPUTER
This is the brain of the robotic arm. Automated sequences are controlled from this central computer. It also has an incorporated collision avoidance algorithm to stop movement when close to another object.

6 ELBOW
At the centre of the arm, this joint bends and extends the robot. As this movement is repeated, the two ends can lift from a surface to mimic a walking motion.

Did you know?
The ESA’s robotic arm can handle 8,000 kilograms

4 LIMB
The two limbs of the smart spacewalker are each five metres in length and are made of carbon fibre.

1 END EFFECTOR
At the ends of this spacewalker are components that can anchor onto the space station. This feature can be used to aid astronauts during spacewalks.

7 EXTRAVEHICULAR ACTIVITY HANDRAIL
When the arm is used to assist spacewalkers, astronauts hold onto these handles for stability.

3 WRIST
The wrist joint can move the end, or hand, of the arm into up, down, left and right positions. This ensures precision when reaching for heavy payloads.

“Space robotics give scientists the opportunity to delve into the harshest environments”

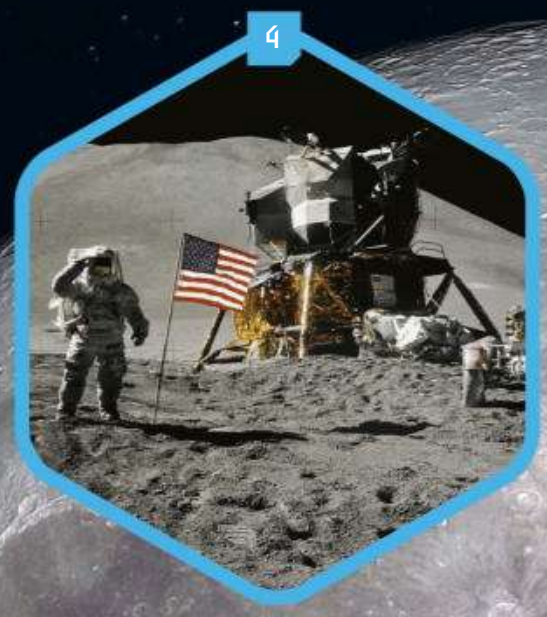
2 CAMERA AND LIGHTING UNIT
Lasers are shone from this unit. When they reflect off objects and return to the arm’s sensors, the robot determines the distance between itself and an object.

© Getty / CNSA / ESA / NASA / Maxar Technologies

FINDING MOON ROCKS

Why astronauts brought lunar rubble back to Earth

WORDS **SCOTT DUTFIELD**



More than 200,000 miles from Earth is a round lump of rock that has fascinated humankind for thousands of years: our natural satellite, the Moon. In 1969, humans made the valiant journey beyond our atmosphere and across the vacuum of space to bring some of it home. Before astronauts walked on the Moon's surface, it was widely believed that Earth's natural satellite was merely a space rock that had drifted too close to Earth's gravitational grasp and become trapped within it. However, thanks to the rocks brought back to Earth for study, the theory behind the Moon's origin has shifted in favour of the giant impact hypothesis.

The majority of the Moon is made up of anorthosite, a calcium-rich rock that consists mostly of a mineral known as plagioclase feldspar. These minerals are formed from the solidification of hot molten lava. It's thought that throughout the Moon's existence, countless impacts from crater-forming meteorites have pockmarked its surface, which was once a raging ocean of molten rock before it cooled and solidified. Moon rocks brought back by astronauts have also revealed the biggest collision in the Moon's history.

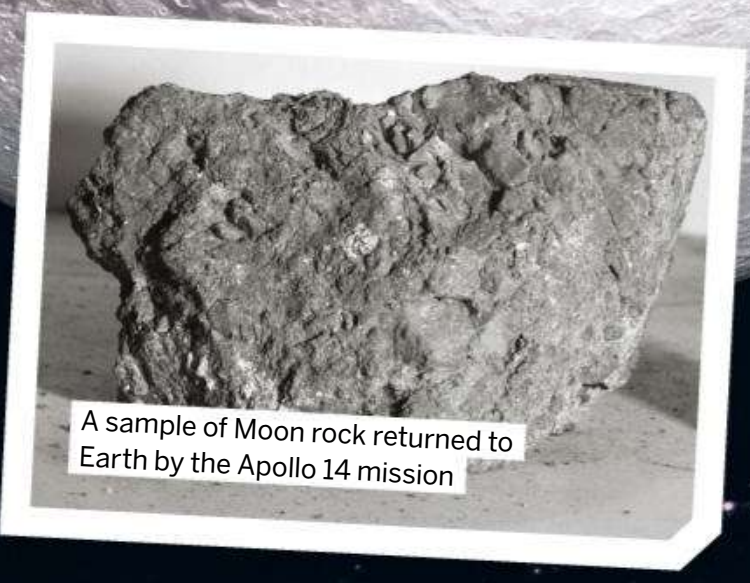
Rather than simply gravitationally leashing it, Earth played a part in the Moon's creation when it collided with a huge extraterrestrial object known as Theia. The collision chipped away at Earth's surface, the fragments of which came together with broken pieces of Theia and formed the Moon around 4.5 billion years ago.

Did you know?

The Moon formed in a matter of hours

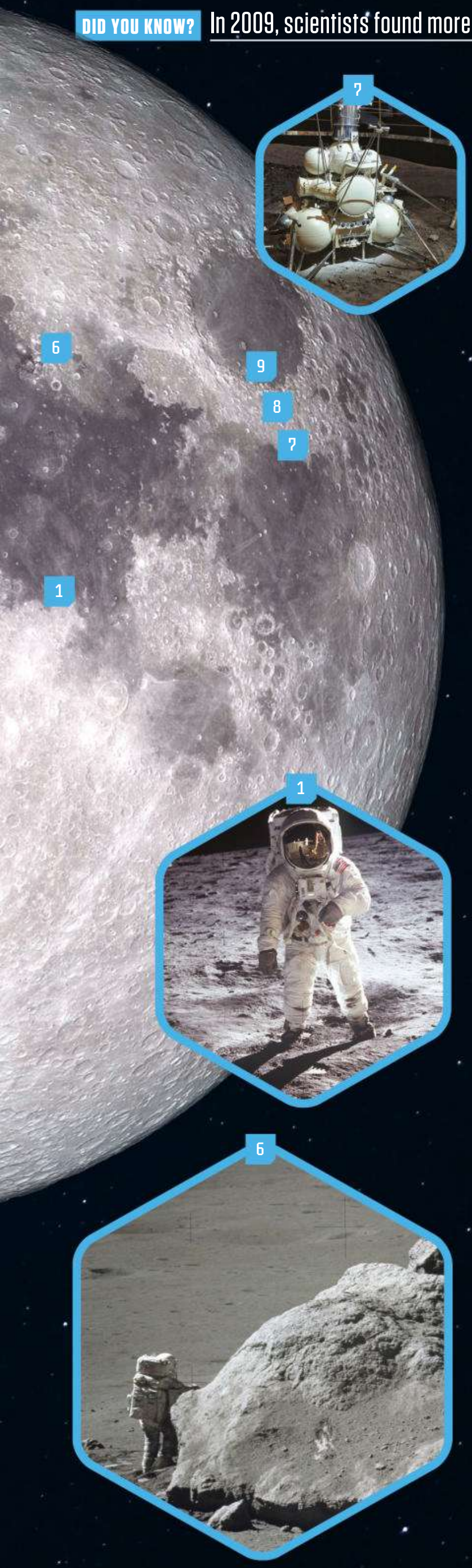
In 2019, scientists studying a breccia sample – a rock consisting of fragments of other stones and material – from the Apollo 14 mission discovered that some pieces of the sample didn't originate from the Moon, but from terrestrial rock found on Earth.

Discoveries about the history of the Moon are continually being made from the samples retrieved by astronauts and space robots over the last few decades. Almost 50 years after the Apollo 17 mission, scientists studying some of the retrieved lunar samples at the University of Hawaii have discovered the Moon may have cooled down much quicker after its formation than thought. It's been accepted that the Moon spent 100 million years cooling down, but chemical variations in some of the sample's minerals suggest that it only took 20 million years for the Moon to cool down. Each year around 400 lunar samples from the Apollo missions are distributed to institutes for further research across the globe.



A sample of Moon rock returned to Earth by the Apollo 14 mission

DID YOU KNOW? In 2009, scientists found more than 40 craters thought to contain water ice



MOON ROCK MISSIONS

Where have astronauts and space robots collected lunar samples from?

1 APOLLO 11
TRANQUILITY BASE
16 TO 24 JULY 1969
Astronauts Neil Armstrong and Buzz Aldrin became the first people to walk on the Moon. During their 21 hours and 36 minutes on the surface, they collected around 22 kilograms of lunar samples.

2 APOLLO 12
OCEANUS PROCELLARUM
14 TO 24 NOVEMBER 1969
On the second successful mission to the Moon, astronauts Alan Bean and Charles Conrad retrieved 12 lunar samples weighing a total of 34 kilograms.

3 APOLLO 14
FRA MAURO
31 JANUARY TO 9 FEBRUARY 1971
Astronaut Alan Shepard trekked more than 2,700 metres across the Moon's surface, using a hand cart to collect samples that amounted to around 43 kilograms.

4 APOLLO 15
HADLEY-APENNINE
26 JULY TO 7 AUGUST 1971
Around 77 kilograms of lunar rock was ferried around the Moon in a space car called the Lunar Roving Vehicle (LRV) by astronauts David Scott and James Irwin.

5 APOLLO 16
DESCARTES HIGHLANDS
16 TO 27 APRIL 1972
Using the LRV, astronauts Charles Duke and John Young travelled over 16 miles across three moonwalks to collect a whopping 95 kilograms of lunar samples.

6 APOLLO 17
TAURUS-LITTROW
7 TO 19 DECEMBER 1972
In the last Apollo mission that retrieved rock samples, astronauts Gene Cernan and Harrison Schmitt spent three days on the surface and collected 110 kilograms of samples to bring home.

7 LUNA 16
MARE FECUNDITATIS
12 TO 24 SEPTEMBER 1970
During a trip to the Moon by the Soviet Union, an unmanned robotic probe scooped up 101 grams of lunar soil and successfully returned it to Earth.

8 LUNA 20
TERRA APOLLONIUS
14 TO 25 FEBRUARY 1972
Similarly to Luna 16, another unmanned probe landed on the Moon's surface and grabbed 30 grams of lunar soil.

9 LUNA 24
MARE CRISIUM
9 TO 22 AUGUST 1976
Around 170 grams of soil was taken by a probe with the use of a robotic arm and rill. This was the third and final mission by the Soviet Union to retrieve Moon rock.

10 CHANG'E 5
MONS RÜMKER
23 NOVEMBER TO 16 DECEMBER 2020
In China's first lunar sample-return mission, the unmanned Chang'e 5 probe dug as deep as two metres into the surface to extract around two kilograms of rock to bring back for study on Earth.

CHANG'E 6

SOUTH POLE-AITKEN BASIN
MAY 2024
Next year, China could become the first nation to reach a previously unexplored part of the Moon. Chang'e 6 will be the first mission to take samples on the far side of the Moon, from the lunar south pole. It's particularly difficult to safely land on that side of the Moon because it never faces Earth. To get a better view of where Chang'e 6 will land, China will send out a scout satellite called Queqiao 2 to act as a communications middleman between the spacecraft and the team back on Earth. The entire Chang'e 6 mission is set to last 53 days and aims to collect up to two kilograms of lunar material.

© Getty / Alamy / China News Service

DIY POWER

Discover the science and technology behind the power tools in your toolbox

WORDS **SCOTT DUTFIELD**

DID YOU KNOW? Cranial drills are used to bore into the human skull and relieve pressure around the brain

SMOOTH SPINNING ELECTRIC SANDERS

Putting power behind sandpaper, electric sanders use a motor to rapidly expose a surface with abrasive force. First seen in the early 1900s, electric sanders made short work of stripping furniture paint, rounding metal edges and smoothing surfaces. There are typically two main types of sanders. A belt sander uses a drum wrapped in sandpaper, while an orbital sander requires an abrasive disc, held horizontally on a metal plate for circular sanding.

Although they might appear different, they both rely on the same process of abrasion. When a sanding disc rubs against the surface of another material, such as wood, the hard grains of rock on the surface of the disc penetrate the surface of the wood, producing microscopic grooves as they go. The particles of wood that have been excavated from these grooves fly away and layers of the wood are removed, leaving an even surface behind.

The scale of hardness for sanding discs is measured in grits: finer grits are for tackling softer surfaces or producing a polished finish, while coarse grits are used in grinding down hardwood and metal. Along with producing smooth surfaces, sanders also generate a lot of wood and metal dust. To catch the debris, many sanders are equipped with a vacuum device called an aspirator. While the sander is busy grinding down material, the aspirator draws the dust through a series of holes and deposits it into a bag for storage.

Orbital sanders can spin at speeds of around 14,000 orbits per minute

5 TYPES OF ABRASIVE DISCS

1 DIAMOND
Diamonds are bound in robust resin and adhered to abrasive discs that are used to smooth out a variety of materials, such as ceramics, titanium, glass or chrome.

2 SILICON CARBIDE
Made from the natural mineral form of silicon carbonate, which are sharp crystals, it makes quick work of cutting into wood.

3 CERAMIC
Densely packed grains of ceramic minerals are used in sanding discs that tackle hard materials such as stainless steel and aluminium.

4 ZIRCONIA ALUMINA
Made from a combination of aluminium oxide and zirconium dioxide, this self-sharpens every time it's used.

5 ALUMINIUM OXIDE
Used to smooth the rough surfaces of strong materials such as steel, bronze and hardwood.

© Getty / Pferd Disk

DRILLING DEEP

The cordless drills you might find in a typical toolbox today all descend from the portable electric drill, invented in 1917 by Americans S. Duncan Black and Alonzo Decker. However, the first electric corded drills were patented by Australian inventors Arthur James Arnot and William Blanch Brain in 1889. Since then, drills have evolved into all shapes, sizes and strengths.

The mechanism of a power drill is quite straightforward. Power delivered by either a battery or mains electricity drives an electric motor, which rotates the steelhead of a drill, called a chuck. Within the chuck, an array of interchangeable drill bits can be used, either for screwdriving or drilling out holes.

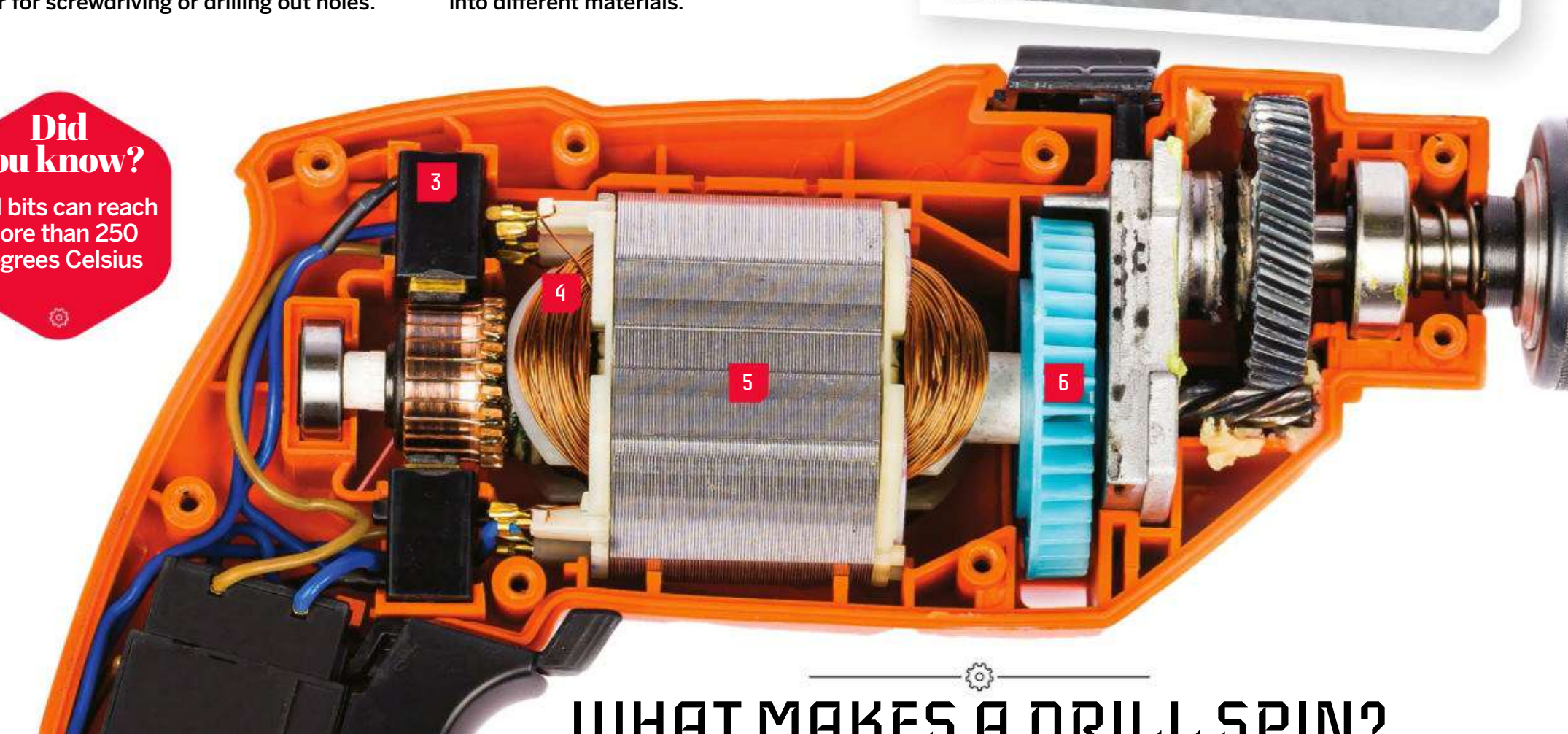
Once the trigger is pulled, the motor will spin the chuck at up to 2,000 revolutions per minute for some models. As the drill bit spins, it generates a force called torque, measured in Newton metres (Nm), turning an object such as a screw. The more torque a drill can produce, the more force can be applied to twisting the screw.

Impact drills, also known as hammer drills, can deliver a little extra oomph when tackling tough screws. Along with a typical chuck, an impact driver has an internal hammer and anvil. When a higher level of torque is required to drive a screw, the hammer hits the anvil, delivering additional force to drive a screw into different materials.

Cordless power drills can last hours on a single battery charge

Did you know?

Drill bits can reach more than 250 degrees Celsius



WHAT MAKES A DRILL SPIN?

These components work together to tighten screws and bore holes

1 POWER SUPPLY
Handheld drills are powered through a mains source or a battery pack. Corded can deliver more power.

2 TRIGGER
Pulling the trigger activates the drill's electric motor and spins the terminal chuck.

3 MOTOR BRUSHES
Made from conductive material such as graphite, the brush delivers an electrical current to the drill's motor commutators.

4 COMMUTATORS
Either end of the drill's armature are copper wires called commutators. These carry the electrical current in a coil, forming an electromagnet that spins the armature.

5 ARMATURE
This is the torque-generating part of the drill motor, which uses electromagnetic force to spin the drill bit.

6 COOLING FAN
To prevent the drill from overheating due to the kinetic energy, an internal fan redirects generated heat to the outside.

7 CLUTCH
The clutch controls the amount of torque needed to drive a screw or bore a hole into materials. This can be manually set by the user.

8 CHUCK
This is the part of the drill that holds the drill bit, which are typically interchangeable for different applications.

DID YOU KNOW? Chainsaws were originally invented as a medical tool to assist with childbirth

SHOOTING NAILS

The humble hammer is no match for the pneumatic power of the nail gun. Powered by pressurised air, nail guns work in a similar way to embed nails into wood. When the trigger is pulled, the air pressure changes within the gun. As compressed air rushes into the device and the internal air pressure changes from low to high, it causes an internal piston to drive downwards. As the piston descends, it forces a nail to fire from its holding barrier into an adjacent surface. As the air escapes the gun, the piston returns to its former position, awaiting its next nail. Other styles of nail guns use small cans of flammable gas instead of compressed air to fire nails. Inside a combustion nail gun, a small amount of gas is released and ignited in a combustion chamber. The force generated from the combustion propels the piston downwards and drives the nail into the wood.

A nail gun can fire a nail at more than 400 metres per second

The jagged teeth of saw blades apply pressure to the material being cut and use friction to tear it apart

SERIOUS SAWS

Since ancient Egypt, people have used metal handsaws to cut through wood, but over thousands of years the handsaw has evolved, with a myriad of shapes, sizes and technological advancements. One of the most recognisable handheld power saws is the circular saw. The first electric handsaw wasn't created until 1923, by French inventors Edmond Michel and Joseph W. Sullivan. Their novel saw used an electrically powered circular blade, which they called the Skilsaw. With a flip of a switch the rotary blade began to violently spin, shredding through any wood fibre that passed across the blade's many teeth.

To get the blade spinning, this pioneering tool utilises a mechanism called a worm drive: a steel spiral called a worm that sits at the end of a cylindrical motor. Nestled within the grooves of the worm are the teeth of the gear, sitting perpendicular to the worm at 90 degrees. Attached to the gear is the saw's steel blade, also sitting at 90 degrees to the worm. As the motor turns the worm, the gear also spins, which turns the blade. The speed at which a circular blade can spin differs between saw models and brands, but the typical revolutions per minute of a circular saw is between 2,700 to 5,000.

To ensure that saw blades are up to the task of cutting wood, concrete or even steel, they are typically made from two components. The majority of the blade's body is made from robust high-carbon steel, whereas the teeth are made from much harder metals, such as carbide. While the blade is spinning thousands of times per minute as it's cutting through material, it's also creating a lot of friction, generating intense heat as a result. Small laser-cut lines called extension slots are cut into the blade to prevent the metal from breaking under high temperature changes. These slots provide space for the blades to expand and contract freely during extreme temperature changes.

Did you know?

The world's longest saw blade is 70 metres long

5 TYPES OF COMMON SAWS

1 RECIPROCATING SAW
The straight blade of a reciprocating saw quickly moves back and forth horizontally. This type of saw is typically used in demolition projects.

2 JIGSAW
Similar to a reciprocating saw, a jigsaw uses a straight blade that rapidly moves in a vertical position. The purpose of this saw is to make more precise cuts and carve shapes.

3 CIRCULAR SAW
Typically used by carpenters and joiners, the spinning blades of a circular saw make quick work of separating wood into desired lengths.

4 CHAINSAW
Ditching the solid blade, a chainsaw uses a bicycle chain bearing sharp teeth, wrapped around a gear wheel. As a motor turns, the chain follows suit, ripping into anything it comes into contact with.

5 MITRE SAW
These saws are able to cut precisely at angles between 45 and 90 degrees when the blade is pulled downwards.

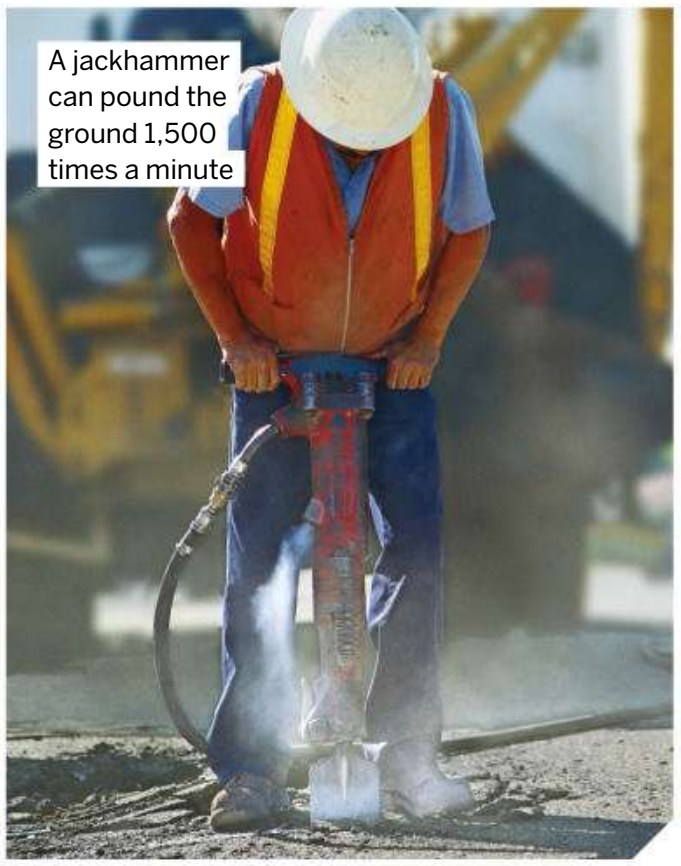
© Getty / Shutterstock

JACKHAMMER DEMOLITION

Jackhammers combine all the force of a falling sledgehammer and the power of the pneumatic drill to make easy work of cracking concrete and turning rock into rubble. Jackhammers were first invented in the 1840s for use in the mining industry. However, their ability to break apart stubborn material has expanded out of caves and onto construction sites around the world.

There are three types of jackhammer: pneumatic, electric and hydraulic. The most commonly used pneumatic hammers rely on compressed air to move an internal piston that drives a chisel at the end of the tool, moving it rapidly back and forth and chipping away at the rock beneath it as it goes. The internal system of the jackhammer is governed by a series of valves that open and close to allow compressed air to quickly flow throughout the tool. Travelling along special pathways within the body of the jackhammer, the compressed air throws a piston up and down as it passes through. Like a blacksmith striking an anvil, the piston slams into the chisel, which in turn transfers that force to the rock, breaking it apart. These devices can be weighty, often around 45 kilograms, and require strong arms to keep them in check.

Electric jackhammers are used in a similar way to the pneumatic variety but rely on motors to convert rotary motion into reciprocating, or back-and-forth motion, to drive a piston and move a chisel. In place of compressed air, hydraulic hammers use pressurised fluid to shift the piston. However, these jackhammers are much heavier and are typically only found at the end of heavy construction machinery.



A jackhammer can pound the ground 1,500 times a minute

INSIDE A JACKHAMMER

How compressed air causes a chisel to crash into concrete and split it into pieces

1 AIR COMPRESSOR
Compressed air is supplied to the jackhammer, typically from a diesel engine air compressor.

2 PRESSURE CHAMBER
The cylindrical body of the jackhammer acts as a chamber to store incoming air.

3 DRIVING THE PISTON
When the trigger of the jackhammer is pulled, a valve is opened to allow compressed air to flow above the piston, driving it downwards.

4 STRIKING THE CHISEL
Also known as the bit, the chisel is struck rapidly by the piston, forcing it to move and hammer into the adjacent material, such as rock.

5 RETURNING THE PISTON
Once the space above the piston is full of compressed air, another valve opens, redirecting the air beneath the piston and driving it back upwards.

6 CHISEL
To withstand the blow of the piston and the impact of concrete or rock, jackhammer chisels are often made from hardened steel.

7 AIR CYCLE
While the trigger is pulled, the jackhammer continues cycling compressed air, causing the chisel to repeatedly impact and break apart material.

DID YOU KNOW? The word ‘laser’ is an acronym for ‘light amplification by stimulated emission of radiation’

RED-HOT SOLDERING GUN

A soldering iron or soldering gun is often an electrician’s best weapon against broken electronics and loose wire connections. At the tip of the soldering gun is a loop of copper. The built-in converter converts the mains source electrical power into a low voltage but high amperage electrical current. This type of electrical current generates heat, making the copper tip of the soldering gun glow with a scorching heat of up to 350 degrees Celsius. The hot tip of a soldering gun is placed against a metal rod, typically made of tin and lead, to melt it so it can act as glue to create a new connection between pieces of metal. This technique can be used to repair wiring, join two pieces of metal and even build circuit boards.

Unlike a soldering iron, a soldering gun uses a trigger to heat up the device

WORKING WITH LASERS

In the world of metalworking, welding is common practice and typically uses intense gas-powered flames to burn away at a metal rod, melting it over the joint of two pieces of metal to stitch them together. But in 1988 American mechanical engineer Marshall Jones invented a new laser-powered alternative. Laser welding technology uses a concentrated beam of light and targets it between two materials, either made of metal or thermoplastic, to join them together. The heat generated by the laser, which can reach up to 3,000 degrees Celsius, fuses the two materials to form a smooth seam.

The types of lasers used in welding can vary. A common type of welding laser is known as a gas or carbon dioxide laser. To produce a laser beam, the molecules in a cocktail of gases including carbon dioxide, nitrogen and helium are exposed to electromagnetic waves. The molecules then become energised and emit light, which is amplified using a series of mirrors. When the beam reaches the desired density, typically 106 to 107 watts per square metre, it’s directed through a nozzle and onto the metal below.

Laser beams aren’t just great for joining two pieces of metal together – they’re equally as handy at cutting metal in half. Along with industrial laser cutting machines that are used to cut sheets of metal, wood and plastic into precise shapes, laser cutters are used in the high-risk decommission of nuclear equipment and material. Containment concrete and pipework are challenging to tackle as they pose a high risk to human health.

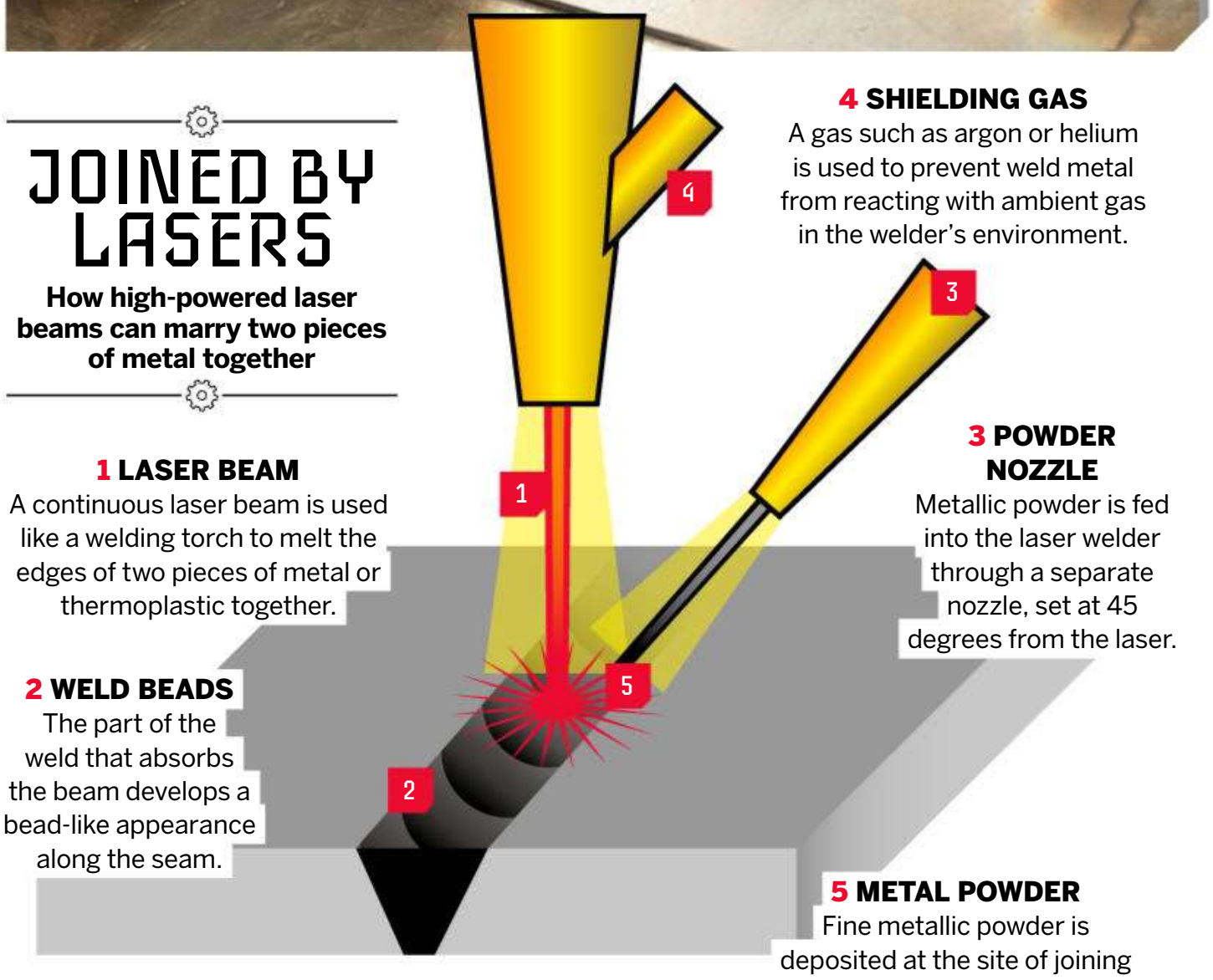
A laser welding torch joining two pieces of metal together

Did you know?

The width of a cutting laser beam is 6.5 millimetres

JOINED BY LASERS

How high-powered laser beams can marry two pieces of metal together



1 LASER BEAM
A continuous laser beam is used like a welding torch to melt the edges of two pieces of metal or thermoplastic together.

2 WELD BEADS
The part of the weld that absorbs the beam develops a bead-like appearance along the seam.

3 POWDER NOZZLE
Metallic powder is fed into the laser welder through a separate nozzle, set at 45 degrees from the laser.

4 SHIELDING GAS
A gas such as argon or helium is used to prevent weld metal from reacting with ambient gas in the welder’s environment.

5 METAL POWDER
Fine metallic powder is deposited at the site of joining to prevent pores or cracks forming in the welded seam.

© Getty / Shutterstock / Illustration by Nicholas Forder

HOW DOES E-INK WORK?

This technology allows e-readers like Kindles to look and read like the pages of a book

WORDS **AILSA HARVEY**

5 USES FOR E-INK

1 SUPERMARKET TAGS
E-ink price tags are used to display prices and other text in supermarkets. This makes each tag reusable when prices or items change.

2 SMARTWATCH FACES
Some watches use E-ink as it provides high contrast in the image and can be viewed from greater angles than LCD or LED watches.

3 DIGITAL BUS STOPS
Solar-powered e-paper displays can be found at some bus stops. The screens display bus timetables and reduce glare from sunlight.

4 MENU BOARDS
To easily update regularly changing menus or temporary dishes, some restaurants use editable e-displays.

5 PETROL PRICES
Large e-displays outside petrol stations clearly present petrol prices with maximum visibility outdoors. These can be synced to the latest prices at any time.

For book lovers, an e-reader such as a Kindle can be either a blessing or a curse, but the technological processes that take place with every virtual page turn are revolutionising publishing industries. Inside e-readers are electrically charged black and white pigments that rearrange themselves to form the words of each downloaded book.

As the opposing black and white pigments' charges repel each other, every micrometre of the screen shows one of the contrasting shades. Compared to other electronic devices, electronic ink products have an impressive battery life. That's because they only use electrical power during the time it takes to rearrange the display. When a new page has formed and is static, no power is being used, allowing you to take as much time as you need on every page. E-readers visually replicate the experience of reading a book, so don't require a backlight. Instead, natural light is reflected off the display and back to your eyes. To aid reading in the dark or dim light, however, a backlight can be turned on.

Did you know?
Kindles have a battery life of up to ten weeks

CAN ELECTRONIC INK BE COLOURED?

For many E-ink applications, such as e-readers, only black and white pigments are needed. Since the main role is to produce text, two-tone devices are the quickest option. However, coloured pigments can be used in addition to the black and white so screens can produce brighter images. Some devices achieve colour by increasing the pigment number from two colours to four, while others use cyan, magenta, yellow and white E-ink to increase the combination of colours. With the latter, around 50,000 colours can be produced through blending as the pigment particles arrange at the screen's surface.

Electrodes can only switch between two charges, so to increase the number of colours, the size of each colour's particles have to be altered. This gives the particles different acceleration rates when they are exposed to different electrical charges. By changing the charge to suit the different particles' movement patterns, the pigments can be precisely arranged into different formats to produce different tones. Although these E-ink devices are more technically advanced, they're usually slower to update each page than a standard black-and-white model.

Technology company Plastic Logic specialises in coloured electronic ink displays

DID YOU KNOW? Thanks to their liquid content, E-ink devices can be flexible or foldable

E-ink is used to make large, curved digital clock displays that have a good battery life

Supermarket E-ink displays can change daily to show deals

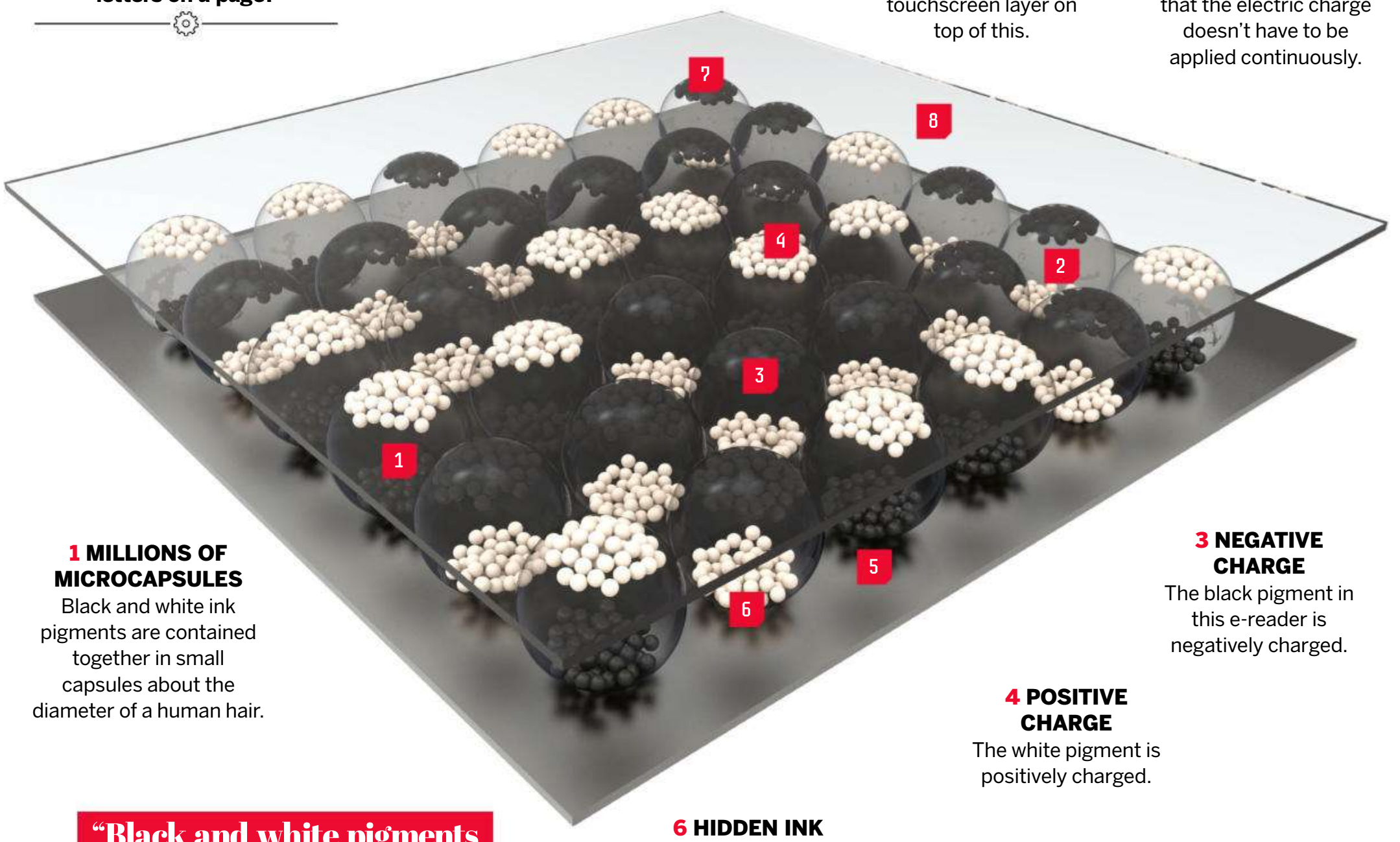
BENEATH E-PAPER

How are black and white pigments arranged into letters on a page?

7 WORD ARRANGEMENT
Black ink that's positioned at the top of the screen makes up millions of similarly charged microcapsules. Together the visible black pigment particles create words or shapes across the screen.

8 CLEAR ELECTRODE
The upper electrode screen is clear so that the pigment is visible. An e-reader will have an additional clear touchscreen layer on top of this.

2 CLEAR FLUID
At the centre of each capsule is a clear fluid. When the charge is removed, the viscous liquid suspends the pigments in place so that the electric charge doesn't have to be applied continuously.



1 MILLIONS OF MICROCAPSULES
Black and white ink pigments are contained together in small capsules about the diameter of a human hair.

3 NEGATIVE CHARGE
The black pigment in this e-reader is negatively charged.

4 POSITIVE CHARGE
The white pigment is positively charged.

"Black and white pigments rearrange themselves to form the words"

6 HIDDEN INK
When ink is forced to the bottom of the microcapsule by the electronic charge, these pigments are hidden from the person viewing the screen.

5 BOTTOM ELECTRODE
When the electrode at the base of a microcapsule is negatively charged, the black pigment is repelled to the top of the screen.

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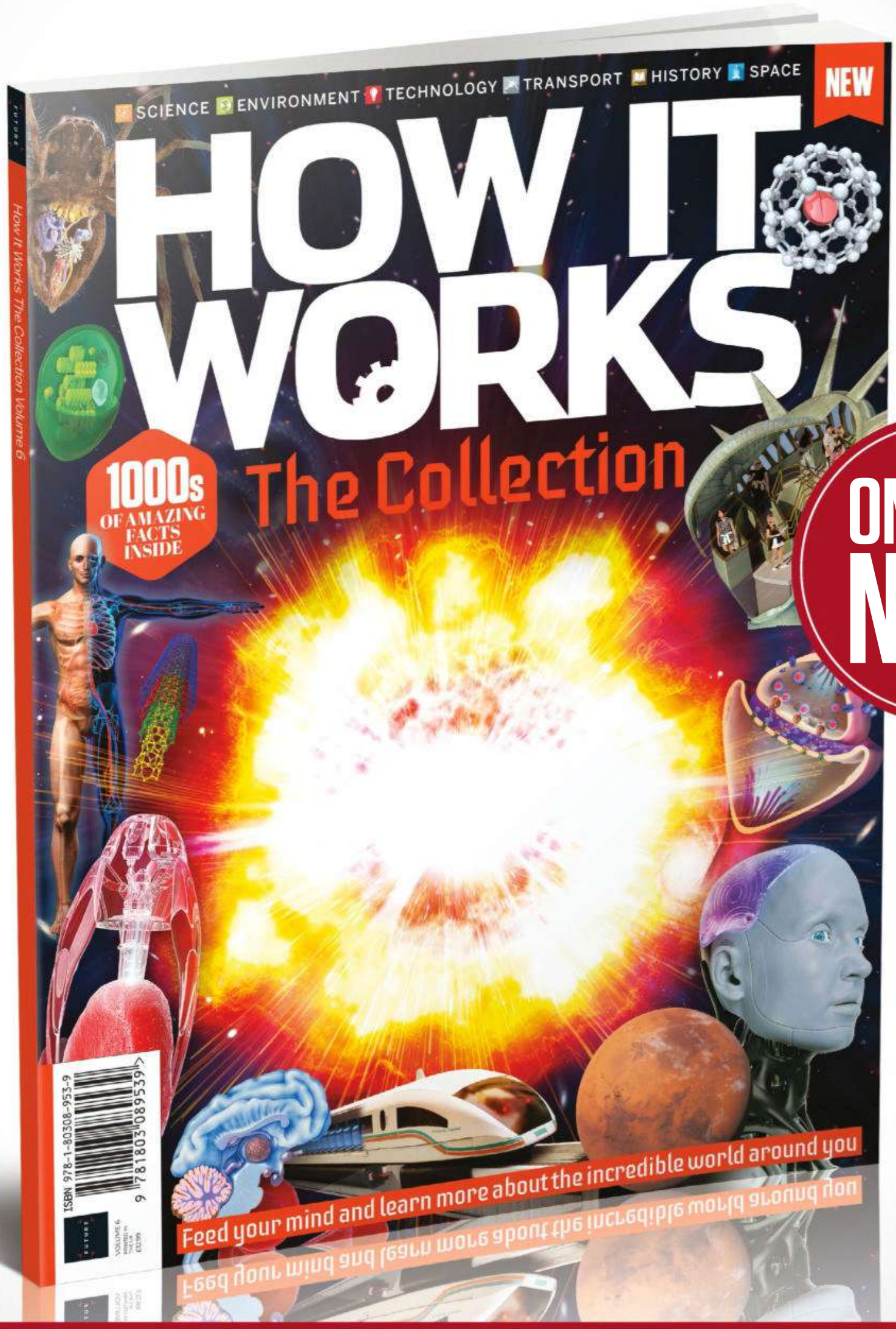

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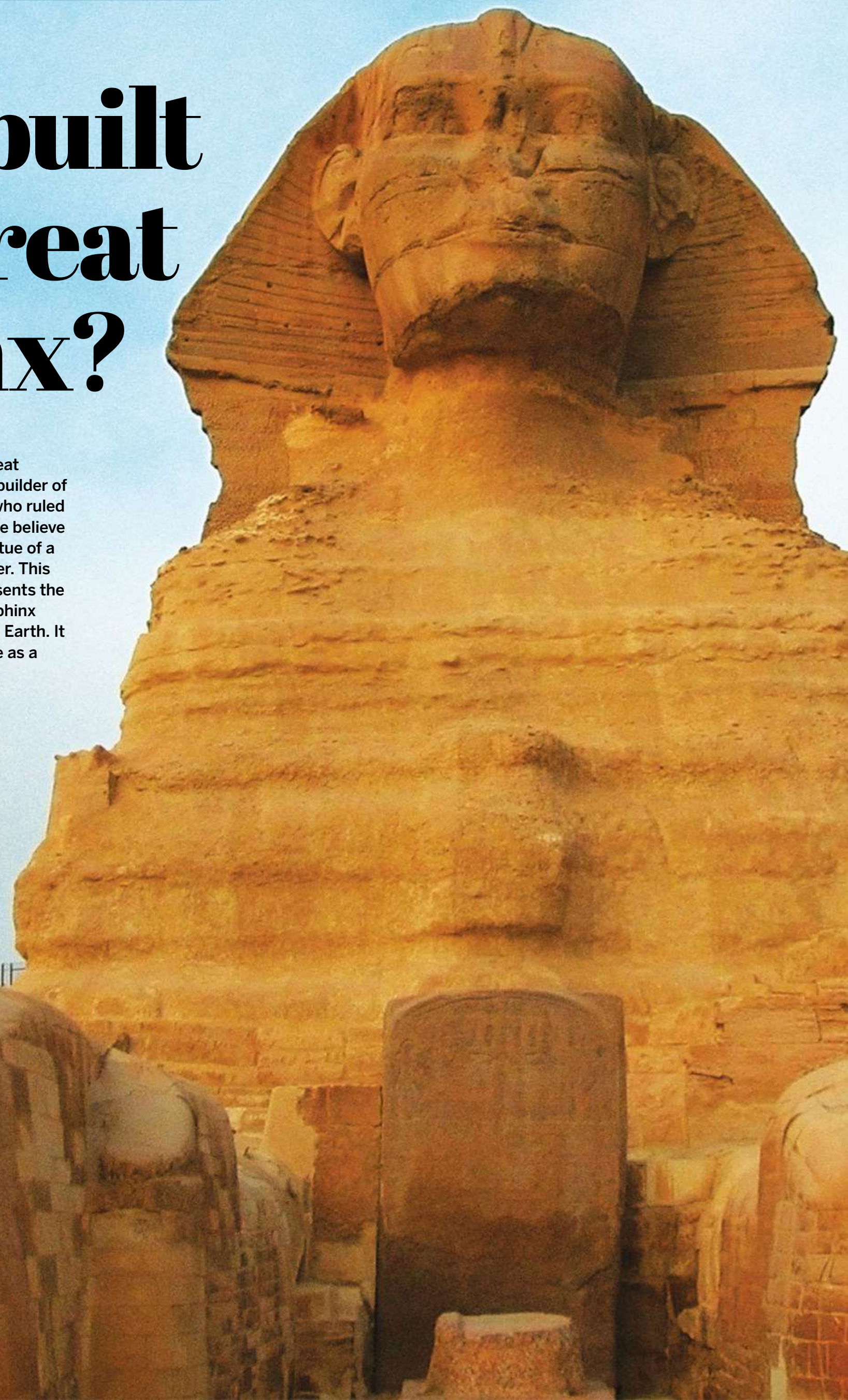
BRAINDUMP

Amazing answers to your curious questions

Who built the Great Sphinx?

Michael Beattie

Most Egyptologists think that the Great Sphinx was built by King Khafre, the builder of the second of the pyramids at Giza, who ruled from around 2558 to 2532 BCE. Some believe the Great Sphinx started out as a statue of a lion, with Khafre's features added later. This combination of man and beast represents the pharaoh's super-human power: the sphinx suggested that the king was a god on Earth. It may also have been intended to serve as a guardian of the king's pyramid.



WHEN WAS THE VERY FIRST BUS SERVICE IN LONDON?

Thomas Farrant

London's first regular bus service was started by George Shillibeer on 4 July 1829. He had seen the omnibus operating successfully in Paris and was inspired to do the same in London. Shillibeer's Omnibus carried up to 20 passengers and was drawn by three horses. There were no fixed bus stops as we know them today – passengers just hailed a bus from the roadside. To stop the bus, passengers either banged on the roof or pulled on reins attached to the driver's arms. Although called Omnibus, meaning 'for all', the fare of one shilling meant only the well-off could afford to use it. The first route ran from Paddington in west London via Regent's Park to Bank in the city. The five-mile journey took about an hour.

WHY ARE LONDON BUSES RED?

Jane O'Connor

The iconic red London bus has a long history. In 1907 at a time when there was fierce competition for passengers, and route numbers had only just been introduced, operators still used a variety of colours to indicate where the bus was going. The largest operator, London General Omnibus Company, decided to make its buses stand out. It chose a spoked wheel as a symbol and the colour red for all its vehicles. When London Transport was eventually formed as a single company in 1933, red was already the predominant colour, so all buses in the Greater London area became red.

WHERE ARE THE DEEPEST LONDON UNDERGROUND STATION PLATFORMS?

Marc Compton-Bennett

At 58.5 metres, the platforms at Hampstead station are the deepest of all the London Underground stations. Hampstead also has the deepest lift shaft on the system at 55.2 metres – that's just 1.2 metres less than the height of Nelson's Column. On 11 April 1954, two new high-speed lifts, which travelled the 55-metre journey in 18 seconds – almost four times as fast as the 1907 lifts they replaced – came into service. They were then the fastest lifts anywhere in the UK. Not surprisingly, the station also has the longest spiral staircase on the system, with a total 310 steps, but a notice advises passengers not to use them.

Why does milk turn sour?

Juliette Williamson

Did you know?

UK dairy farms produce around 15 billion litres of milk in a year

Milk contains a sugar called lactose. It also contains harmless bacteria called *Lactobacillus*, which use lactose for energy and create lactic acid as a by-product. It's the lactic acid which makes milk taste sour. Pasteurising milk kills off harmful bacteria and greatly reduces the number of *Lactobacillus*, ensuring that milk will last up to three weeks in a fridge. *Lactobacillus* is a very useful bacterium as the acidic conditions it creates make a milk protein called casein turn to curd. Without curd we would not have dairy food products like cheese.

© Alamy / Getty

WHAT IS THE MAYAN CALENDAR?

Katherine Cooke

Did you ever have a spirograph? The toy had different plastic wheels that meshed with one another and revolved like a clock mechanism. You had to insert a pen and move it around the wheel to create a series of increasingly complicated circular designs on a sheet of paper beneath. The Mayan calendar worked in a similar way.

The first cycle in the Mayan calendar had 13 numerals, and the second wheel had 20 named days. The two wheels revolved like a cogged mechanism, so it would be 260 days before the same point was reached again as the two circles rotated. This was then meshed with a third wheel of 365 days – known as the 'vague year' – but of 18 months instead of our 12. Each month lasted 20 days, with a 'filler' month of five days. The Maya appear not to have worried about the extra quarter day... that's why it was a 'vague year'. We do allow for this, and that is why every four years we have a leap year, in order to keep our calendar in sync with the movement of the Earth around the Sun.

The Mayan cycles would give a calendar of 18,980 days, or 52 years. For longer time spans there was the 'long count', with a unit of measurement called the baktun, of 144,000 days. 14 of these baktun have passed since the cycle started in 3114 BCE, and the last one ended on 23 December 2012 – 1,872,000 days later.

People speculated that the end of this period of time would be marked by a terrible cataclysm that would wipe out the human race, though the Mayan calendar projects dates of anniversaries well into the future, long after 2012.

Can honey go bad?

Eve Lynch

Honey is the only food that does not go off – indeed, honey found in King Tutankhamun's tomb was still edible. It has a high sugar content and antibiotic properties that act as preservatives. Over time, honey becomes cloudy as the sugar crystallises, but this does not spoil it – you can dissolve the sugar by heating it gently. If moisture gets into the honey, though, yeast can grow, ferment and spoil the foodstuff, but so long as it is kept tightly sealed honey can keep indefinitely.

WHAT ARE FLEAS?

Toby Connor

Fleas are small, reddish-brown wingless insects that feed on the blood of mammals and birds. They are compressed side to side so that they can move through fur and feathers easily and have long legs that let them jump up to 100 times their height. They can survive for months without food and their young can live in our carpets and bedding. Flea bites are itchy and can cause allergic reactions. Fleas can also carry diseases such as bubonic plague and myxomatosis.

WHAT'S THE BEST WAY TO PRESERVE ANCIENT ARTEFACTS?

Jon Wardle

It really depends on what you've found. There's no 'one size fits all' answer. Any conservator would say the technique of preservation is dictated by the materials the artefacts are made from. Different materials have different chemical properties and characteristics. An object made of iron might have to be cleaned and kept in a dry environment to prevent it from rusting. A bronze object might need cleaning and keeping in a dry store to prevent bronze disease. A waterlogged wooden object could be treated by soaking it in water-soluble wax and then freeze-drying it. It might be sufficient to clean and glue back together pieces of broken pottery, while gold jewellery might need no intervention at all because gold is an inert, or non-reactive, metal.

Did Atlantis really exist?

Timothy Wilson

The story of Atlantis appears in accounts of two conversations between the Greek philosopher Socrates and his friends Critias and Timaeus, written down by Plato over 2,000 years ago. In the first account Atlantis was said to be a large island opposite the pillars of Hercules, or Straits of Gibraltar. The king of Atlantis wanted to conquer lands around the Mediterranean, but Athens resisted. The island of Atlantis and its people were later destroyed by the sea. In another story the gods bring about the destruction of the island because of the arrogance of its inhabitants. The debate about whether Atlantis really existed has been going on ever since.

Some have claimed to have found ruins of sunken cities beneath the sea. One intriguing possibility is that the story of Atlantis is an account of the destruction of the island of Santorini in a volcanic eruption, which is said to have brought Minoan power on Crete to an end. The story of Atlantis may simply be a warning about what happens to people who think themselves all powerful. Or it may be a half-remembered story about the eruption of Santorini. Whatever the case, it has captured our imagination and will continue to feature in films and books.

Did you know?

Santorini's volcano erupted in the 16th century BCE

HOW CAN WE AGE METAL ITEMS?

Mac Naylor

There isn't an intrinsic method of dating metal as there is for wooden objects, like radiocarbon dating or tree-ring dating. Much depends on the assessment of the object. For instance, an axehead made of bronze is likely to date from the Bronze Age, before knowledge of how to make iron. The date of the discovery of metal-working is going to vary in different parts of the world, but in Britain it will be towards the end of the third millennium BCE – roughly 2300 to 2000 BCE. The method of working the metal is also a crucial factor for ageing. Casting of iron only became possible during the Industrial Revolution in Northwest Europe, for example.

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How old is Earth?

Alistair Roberts

Our home planet is about 4.5 billion years old. This date is based on samples from Earth, meteorites and the Moon, which all come from when Earth first formed. Scientists have looked at radioactive chemicals in the rocks that react into new chemicals over a certain period of time. By working out how many times this reaction has taken place, scientists are then able to determine the age of the rock.

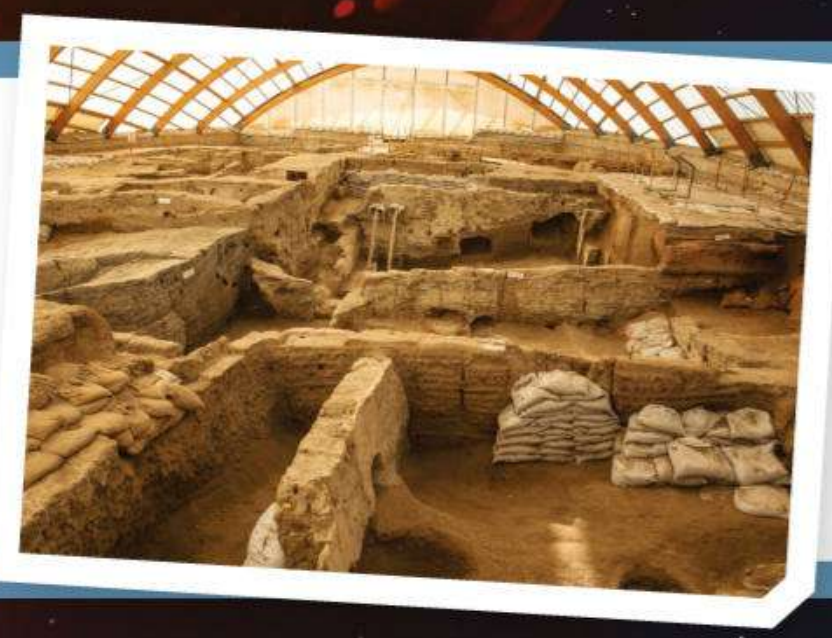
Did you know?

The Moon is a similar age to Earth, forming at the same time

WHAT'S THE BIGGEST ARCHAEOLOGICAL SITE?

Lucy Bailey

The prehistoric site of Çatalhöyük in Turkey covers about 32 acres, while the Palace of Knossos in Crete, Greece, covered an area of about 13,000 square metres. Pompeii covers an area of 145 acres and has been described as 'the most complete urban excavation ever undertaken'. But this is tiny in comparison to the ruins of the temple complex of Angkor Wat in Cambodia, which may cover up to 1,160 square miles!



WHO DESIGNED THE B-TYPE BUS?

Rob Browne

Frank Searle joined the London General Omnibus Company (LGOC) in 1907 as chief engineer. He knew traffic conditions in London required a vehicle of rugged design and used knowledge gained through the development of experimental motor buses to produce the B-type in 1910 – the first reliable mass-produced motor bus. The 34-seat double-decker was relatively quiet, easily maintained and became hugely successful. Although slow and open to the elements, millions of Londoners depended on it to get to work. In just a few years, by 1914, over 3,000 vehicles were in service – and London's last horse-powered bus was withdrawn.

CAN AN ELEPHANT JUMP?

Laura Turner

As the world's largest land animal, weighing several tonnes, elephants are simply too heavy to jump. Their bone structure prevents them from bending their legs enough to push themselves off the ground. Elephants do not have natural predators, so they did not need to be able to jump to improve their chances of survival. Elephants don't even like standing on two legs, although they can be trained to do so.

WHY WEREN'T PEOPLE ELECTROCUTED IF THEY STEPPED ON A TRAM TRACK?

Maria Forrest

The supply of electricity to London trams was designed to be safe and prevent people getting hurt. One side of the supply was earthed, and the live supply was placed out of reach. In the overhead system, the live wire was over six metres above the roadway. In the conduit system the live rail was buried in a channel in the road. Underneath the tram, a 'plough' reached down into the conduit to connect with the electricity supply, which drove the tram.

What gives rubies their distinctive red colouring?

Ruby Robinson

Ruby is the red variety of the mineral corundum. In the structure of atoms which make up a ruby, small amounts of chromium – normally about one per cent – can replace aluminium. In pure corundum, which is colourless, all the energy levels in the aluminium and oxygen are occupied by paired electrons. In chromium, however, six electrons are available for bonding, but only three are required – this leaves partially filled energy levels. Electrons in these can absorb energy from visible light. The energy remaining corresponds to red light in the spectrum. Simultaneously, ruby will absorb energy in the ultraviolet and re-emit it in the visible part of the spectrum as red light. The red colour is therefore ultimately caused by the presence of chromium.

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The latest book releases for curious minds

DISGUSTINGLY DELICIOUS

COW TESTICLES, FROG SHAKES AND MAGGOT CHEESE ARE ON THE MENU

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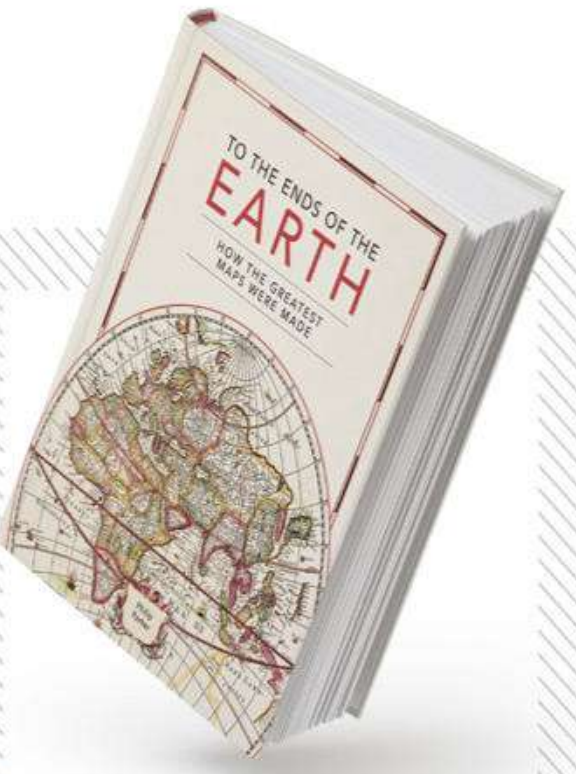
It's tough to pick a single foodstuff in *Disgustingly Delicious* that the thought of eating doesn't immediately turn our stomachs. Why don't we start with the French delicacy 'Escargots de Bourgogne', or snails? They are traditionally sautéed in butter with garlic and parsley, then picked from their shells and eaten on crusty bread. These critters might not be to your taste, but once prepared they're each a tiny morsel with a slightly chewy texture that take up the pleasant savoury flavour of the stock they're cooked in.

If you're a little adventurous with your food and can get past the thought of them alive, sliding into the compost heap in your garden, then you might even enjoy eating snails. They're much less of an acquired taste than the fermented dishes you might encounter around the Arctic Circle, like hákarl: a Greenland shark that has been buried for up to 12 weeks before the rancid-smelling and putrefying fish is dug up and hung for a few months. Or Sardinia's casu marzu, a perfectly decent soft cheese that's been left for flies to lay eggs in. When the maggots have hatched and begun feasting on the cheese, turning it into a weeping yellow heap with an overwhelmingly pungent odour, then it's considered ready to eat. Unsurprisingly, given that there are still live maggots inside it, eating this delicacy can give you a nasty case of food poisoning, and the sale of casu marzu is actually illegal in Italy.

Author Soledad Romero Mariño has picked the cream of the most repellant dishes served in countries around the world for this book, though ultimately it depends on where you were brought up. "It's as if we are brainwashed from a young age about what is disgusting and what is not," says Andreas Ahrens, director of the Disgusting Food Museum in Sweden, in the prologue.

"The most repellant dishes served in countries around the world"

The world delicacies have been chosen for their interesting origins as well as how much they might nauseate someone with a Western palate – whether they were invented in leaner and more desperate times when people couldn't afford to waste food, as a means of preservation, or simply because the main ingredient of the dish is as nutritious as it is disgusting. Coupled with Montse Galbany's comic book illustrations, *Disgustingly Delicious* is an entertaining read with dishes that will put the most horrifying bushtucker trial in the shade. Kids will love it.



TO THE ENDS OF THE EARTH

HOW THE GREATEST MAPS WERE MADE

AUTHOR **PHILIP PARKER**
PUBLISHER **IVY PRESS**
PRICE **£25 / $35**
RELEASE **14 SEPTEMBER**

From the stone-carved maps of humankind's earliest settlements to outlining the entire world on a rotating globe, discover how the world came to see itself through its maps. Throughout *To the Ends of the Earth*, you'll discover the wide array of tools and techniques used to create maps during the evolution of cartography, such as Babylonian maps made from clay and the invention of aerial photography to create digital maps. You'll also meet the many great minds that shaped our understanding of geography, such as the Alexandrian mathematician Claudius Ptolemy, who first used the terms 'latitude' and 'longitude'. Amazing photographs of some of the most elaborate and detailed maps ever created fill the pages of this book, including the awe-inspiring Carta marina, produced by Swedish geographer Olaus Magnus.

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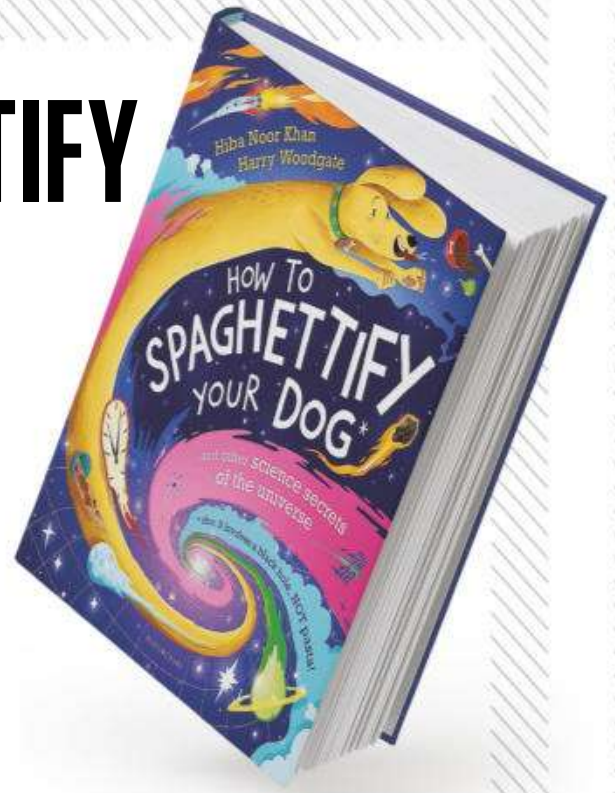
RELEASE **17 AUGUST**



Bringing whimsy to the world of science, this children's book is a perfect example of how to make physics fun. From simple laws of physics, such as understanding pressure and the structure of an atom, to mind-boggling black holes and galactic mergers, *How to Spaghettify your Dog* introduces children to a wide range of new and exciting discoveries in science. It's also packed with fun facts, with heaps of experiments and activities to do at home, such as building a fruit solar system and how to make instant ice. *How to Spaghettify your Dog* brilliantly takes complex concepts in science and breaks them down into digestible nuggets of knowledge for all to enjoy. Every page is filled with vibrant and engaging illustrations that will surely inspire the next generation of budding physicists to don their lab coats and contemplate the curiosities of the cosmos.

THE DINOSAUR WOMAN

JUMP BACK IN TIME AND MEET PALAEONTOLOGIST MARY ANNING

AUTHOR **BRUNELLA COSTAGLIOLA**
ILLUSTRATOR **VALERIO MAZZOLI**
PUBLISHER **WEE B. BOOKS**
PRICE **£9.99 / $10.99**
RELEASE **OUT NOW**

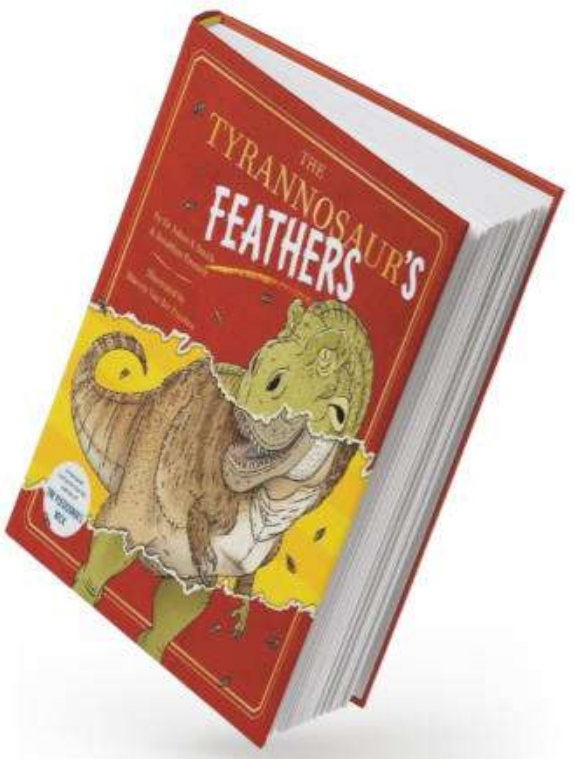
Join Alex, Ella and Layla on a trip to Dorset, England, in this captivating time travel adventure. In *The Dinosaur Woman* you will be transported with the characters to 1830 and get to meet a pioneering female fossil collector. When the three children encounter a painting while playing together, they're intrigued by one figure – a woman who is searching for dinosaurs. They later get to meet the woman in the painting as a bizarre series of events places them into the scene of the artwork. That woman turns out to be Mary Anning, and the stories she tells of her experience as a dinosaur discoverer and woman of science will fill the reader with aspiration. The storyline is expertly written to incorporate not just fascinating details of the palaeontologist's life, but other facts about the environment. *The Dinosaur Woman* is text-heavy with a few intricate cartoon illustrations, but is ideal for any primary-age reader with an interest in science. By incorporating science, history and science fiction, it's a fun introduction to palaeontology.

THE TYRANNOSAUR'S FEATHERS

THIS DINOSAUR IS GETTING A MAKEOVER

AUTHOR **DR ADAM S. SMITH AND JONATHAN EMMETT**
ILLUSTRATOR **STIEVEN VAN DER POORTEN**
PUBLISHER **UCLAN PUBLISHING**
PRICE **£7.99 (APPROX. $10.50)**
RELEASE **OUT NOW**

What does a *Tyrannosaurus rex* look like? Feathers may not be the first thing in your description of this dinosaur, but palaeontologists are continually uncovering new features of these animals that we were previously unaware of. In this humorous, factual and beautifully illustrated book, the authors explain to children how the image of the *Tyrannosaur* has changed since the latest scientific evidence was published. A dinosaur in the familiar *T. rex* image greets readers with its giant green body, scaly back and long tail trailing on the ground. However, it's interrupted by a velociraptor – the *T. rex*'s distant theropod cousin – who wants to change some of the *Tyrannosaur*'s physical features. As the two dinosaurs converse, the velociraptor transforms the *T. rex*'s features by following the latest research as its guide. The result might be much less recognisable, but many of the main characteristics remain in place. Discover how a mislaying of fossil bones and incomplete collections have created an inaccurate image of this dinosaur species and learn about the exciting findings yet to come.



BRAIN GYM

Give your brain a puzzle workout

Sudoku

Complete the grid so that each row, column and 3x3 box contains the numbers 1 to 9

EASY

			5		6	4	2	
6	8	2				9		
5	9		2	3	8			
			6			1	3	
2	6		4				8	9
9		7		5	1			
	1	5	3	6	2	7		4
		6	9			8	1	
		9	1	8			6	

MEDIUM

1			9	8			2	
5	6		3					
2				5		6		4
		5				4	9	
6	9		2	1	3	5	7	
					4			
	7			6	5		8	2
8								
4		6		2	1			7

HARD

	3		9	8		6	2	4
		4	1					
					4		5	
				2	5		1	
1		8		7				3
								7
6	2	9						
		7		6			9	
			4					1

Word search

Find the following words

EVOLUTION
OYSTER
STORM
MOHS
MEAT
BLOOD
MOON
ROBOT
DIY
BIKE
CHANNEL
CRANE

E	V	O	L	U	T	I	O	N	D	I	W	S	E	M
C	N	E	O	Y	S	T	A	R	C	K	D	B	U	T
R	E	D	S	E	L	P	O	M	O	T	R	L	E	O
B	I	K	E	A	T	B	L	O	D	O	M	O	Q	B
A	M	O	H	G	F	J	M	E	A	T	X	O	W	O
O	Y	S	U	W	E	N	D	I	O	O	M	D	Z	R
C	H	A	M	O	O	N	C	R	A	N	I	E	B	I
R	K	E	S	T	Y	O	R	M	L	Y	B	O	O	N
A	Y	M	O	S	H	S	E	V	J	E	A	L	O	P
N	M	Y	E	A	T	Y	T	O	L	C	Y	K	D	A
E	U	M	T	L	I	N	D	E	A	C	R	A	N	U
R	O	R	B	O	C	V	O	L	R	U	T	I	O	N
E	V	O	B	C	H	A	N	N	E	L	J	I	X	R
D	I	T	Y	E	C	K	E	L	O	V	E	Y	C	A
L	U	S	N	A	M	L	O	O	D	Y	M	O	H	S

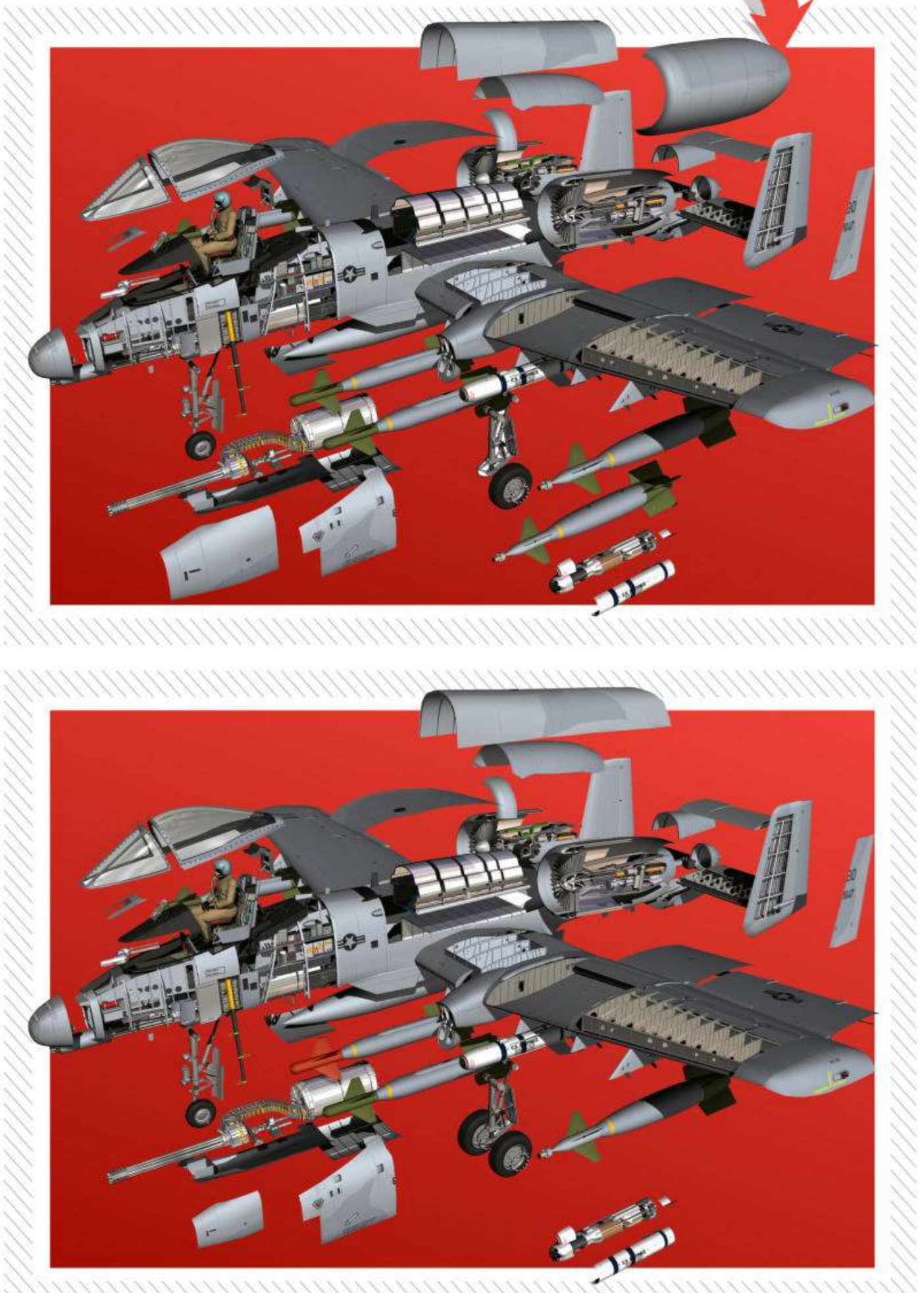
What is it?

Hint:
Ink for the digital age

A

Spot the difference

See if you can find all six changes between the images below



QUICKFIRE QUESTIONS

Q1 What does a Geiger counter measure?

- Atmospheric pressure
- Ionising radiation
- Earthquake energy
- Wind speed

Q2 What does the acronym CPU stand for?

- Computer processing unit
- Core partition unit
- Central processing unit
- Computer partition unit

Q3 Which Apollo mission first put humans on the Moon?

- 1
- 11
- 13
- 18

Q4 How much does the world's smallest mammal weigh?

- 500 grams
- 200 grams
- 20 grams
- 2.0 grams

Q5 Which ocean has the world's deepest trench?

- Atlantic
- Indian
- Arctic
- Pacific

Q6 Which of these human organs is the biggest?

- Liver
- Brain
- Heart
- Pancreas

Answers

Find the solutions to last issue's puzzle pages

Q1 SPIRAL
Q2 KERATIN
Q3 MOLAR
Q4 COPPER
Q5 2,700 YEARS AGO
Q6 C

What is it?

CANDY FLOSS

Spot the difference

© Getty

MAKE A CD GREENHOUSE

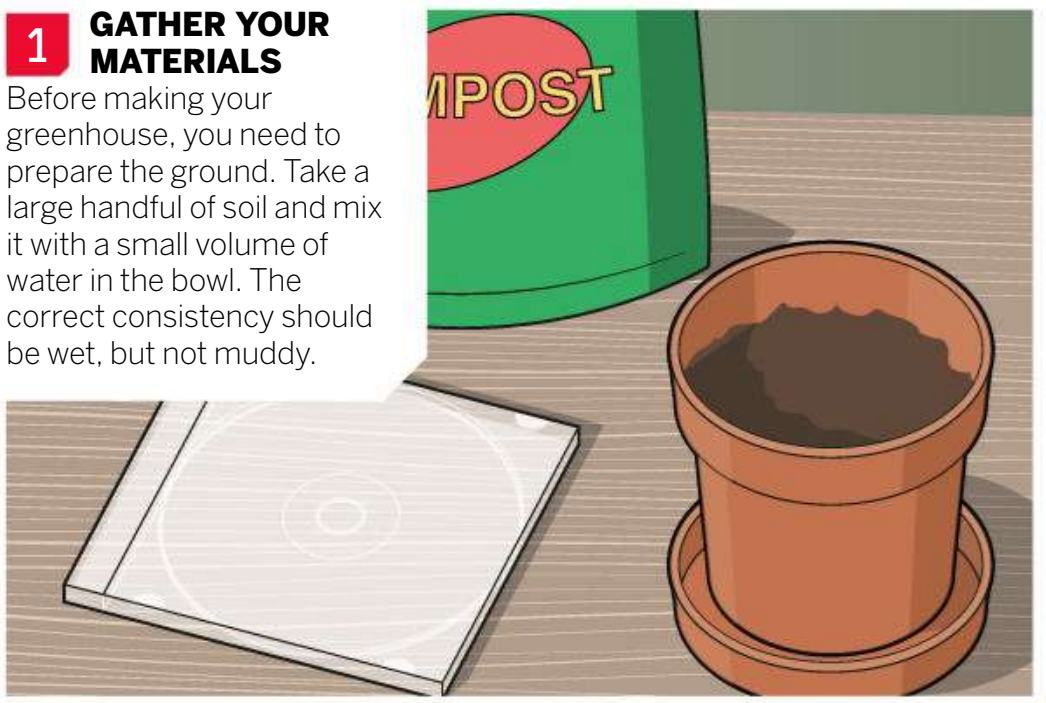
Recycle transparent CD cases and watch seeds produce roots and shoots

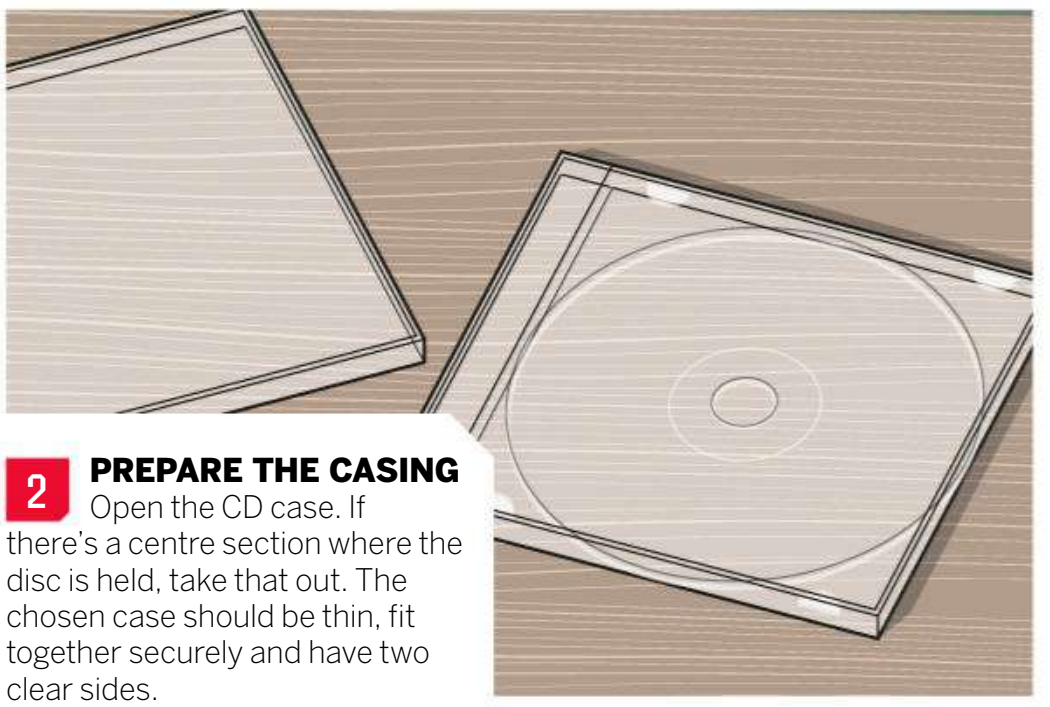
KIT LIST

- Seeds
- Potting soil
- CD case or similar clear case
- Small bowl
- Water and spray bottle
- Clear tape

1 GATHER YOUR MATERIALS

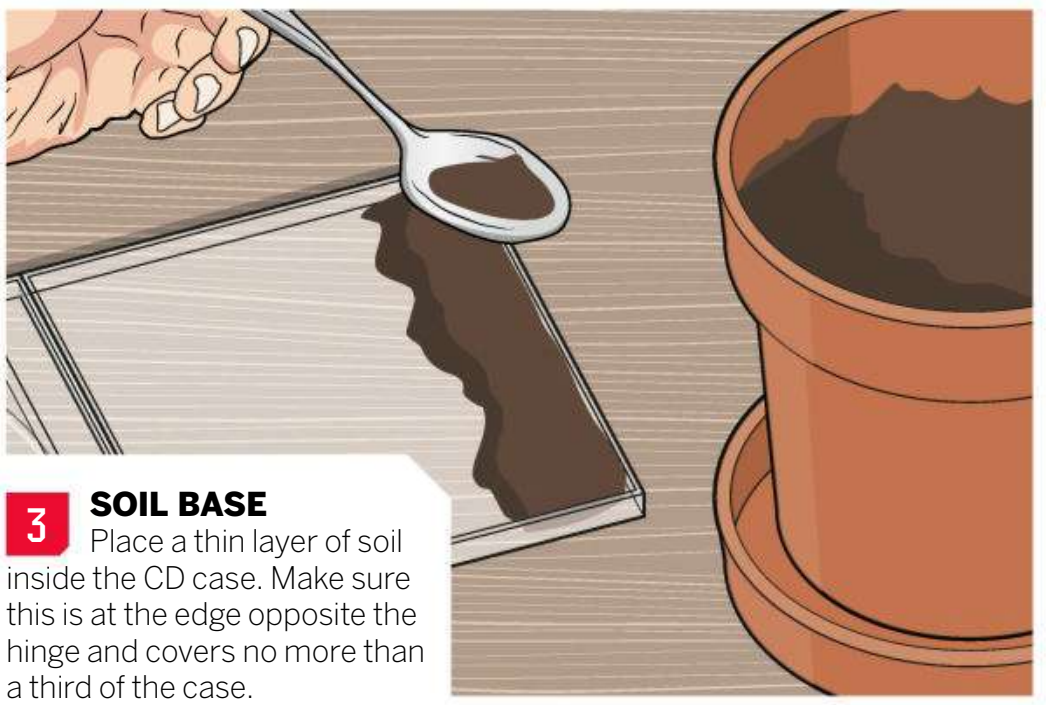
Before making your greenhouse, you need to prepare the ground. Take a large handful of soil and mix it with a small volume of water in the bowl. The correct consistency should be wet, but not muddy.





2 PREPARE THE CASING

Open the CD case. If there's a centre section where the disc is held, take that out. The chosen case should be thin, fit together securely and have two clear sides.



3 SOIL BASE

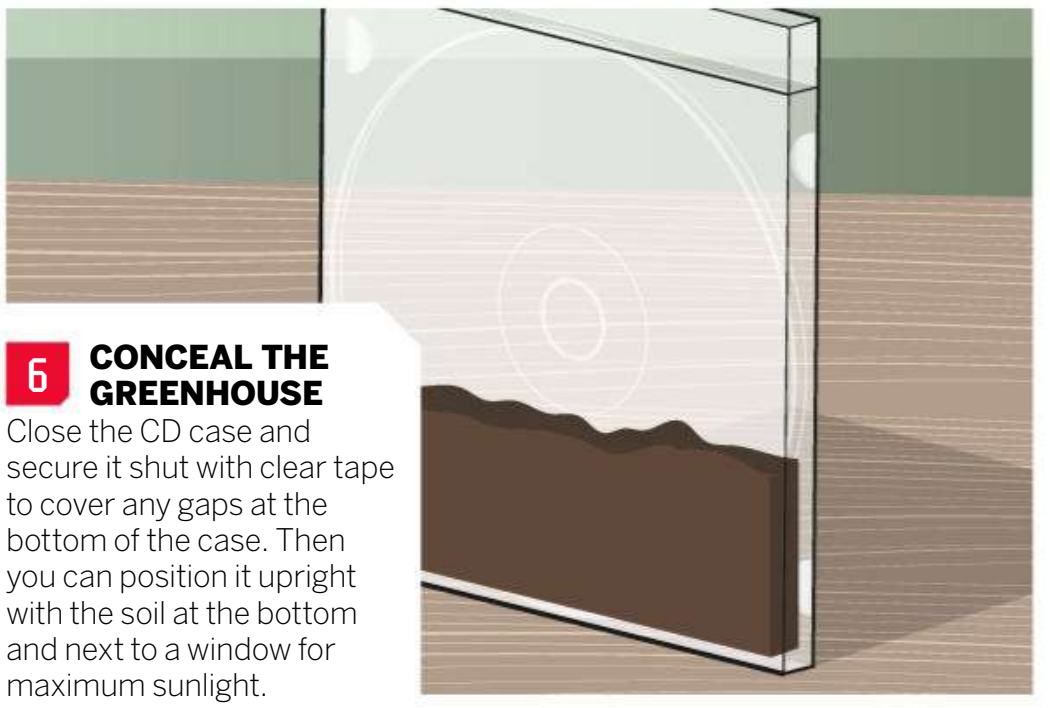
Place a thin layer of soil inside the CD case. Make sure this is at the edge opposite the hinge and covers no more than a third of the case.

4 SPRINKLE THE SEEDS

Generously sprinkle your chosen seeds over the soil in the CD case. You should aim to place these at the centre of the soil.

5 SPRAY AND COVER

Spray the soil at this point if it doesn't feel wet, then cover the top of the seeds with a thin layer of soil.

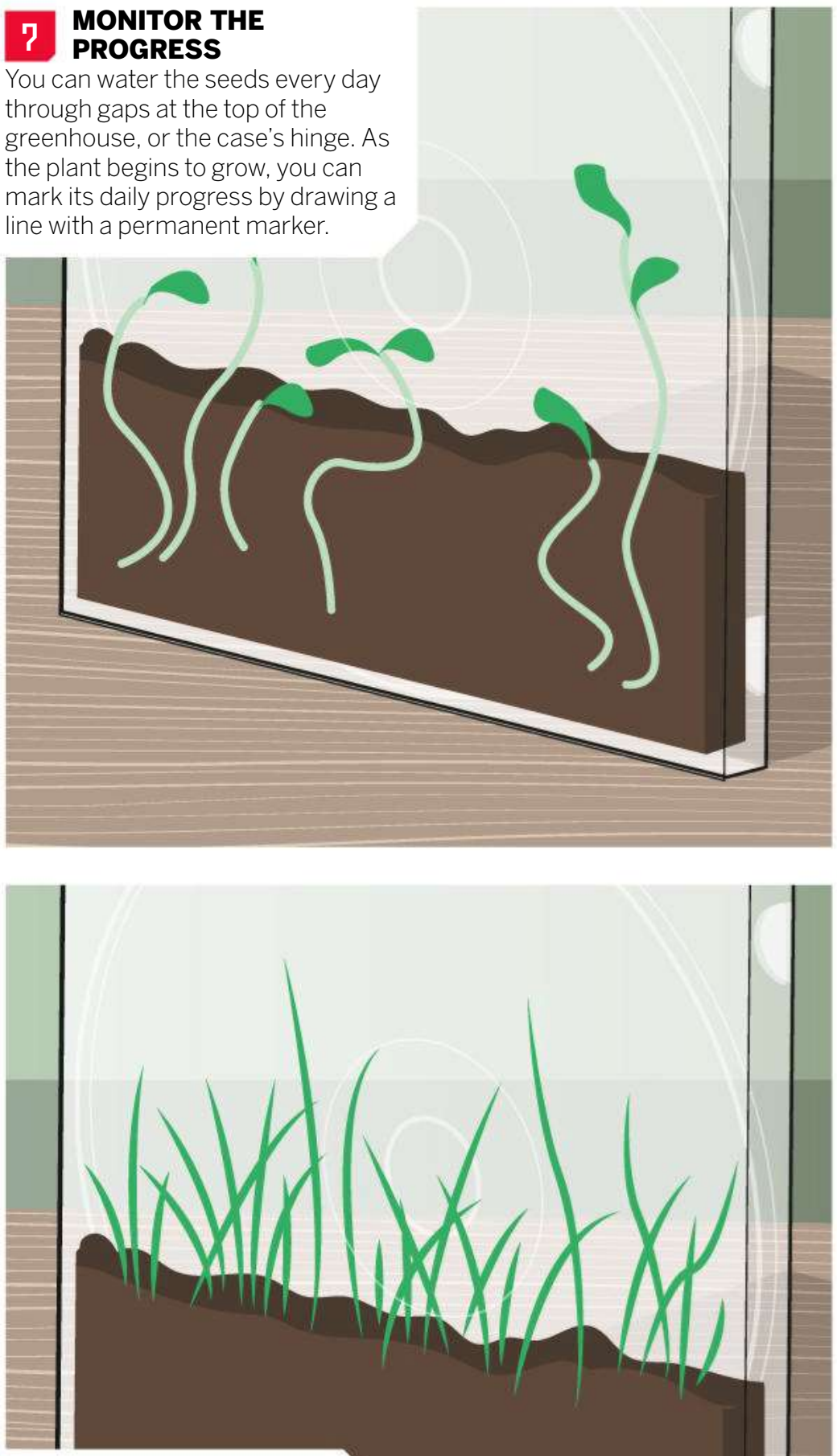


6 CONCEAL THE GREENHOUSE

Close the CD case and secure it shut with clear tape to cover any gaps at the bottom of the case. Then you can position it upright with the soil at the bottom and next to a window for maximum sunlight.

7 MONITOR THE PROGRESS

You can water the seeds every day through gaps at the top of the greenhouse, or the case's hinge. As the plant begins to grow, you can mark its daily progress by drawing a line with a permanent marker.



8 SEND IN YOUR RESULTS

The clear case makes the progress of the plants' roots and shoots visible. You can share pictures of your greenhouse results with us and other readers by sending them to **howitworks@futurenet.com**.

SUMMARY

In this experiment, your aim is to turn a CD container into the perfect place for plant life to grow. A plant needs water, carbon dioxide, sunlight and nutrients. By following each of the steps in this guide, you'll provide the seeds with each of these vital elements. It usually takes a seed up to ten days to begin to sprout, so remain patient and continue to water them. To fully understand the process of a growing seed, observe it regularly – not just after ten days. First you will see the seed case splitting and a green shoot reaching towards the top of the case. Meanwhile, roots will begin to emerge and extend in the opposite direction. These establish a plant's position in the soil and enable it to absorb nutrients.

Had a go? Let us know!

If you've tried out any of our experiments – or conducted some of your own – let us know! Share your photos or videos with us on social media.

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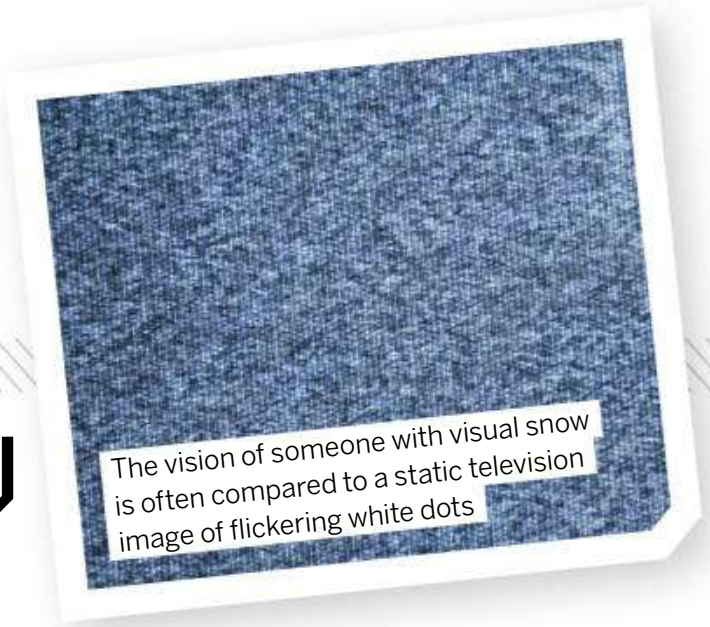
INBOX

Speak your mind

VISUAL SNOW AND SLEEP



The vision of someone with visual snow is often compared to a static television image of flickering white dots

Dear **HIW**,
What effect, if any, would visual snow have on insomnia? It's never dark in my world, but the light is in my brain.
MedTek

Thanks for your question. Visual snow gets its name because those with the disorder see white, black or colourful flickering dots in their vision. This is likely caused by the overstimulation of the part of the brain responsible for image processing: the occipital lobes. Many people who experience visual snow also experience some difficulty sleeping, as the bright images that appear when your eyes are open are also present when you close them. This can be distracting when your body is trying to shut down, and research shows that the time taken to fall asleep is generally greater in those with visual snow syndrome. For some people, the visual effects are intensified at night, making it more likely that sleeping difficulties will arise.

Visual snow can range in severity, impacting people differently, and sleep deprivation can actually make the symptoms worse. In one study, 40 per cent of the visual snow patients monitored showed signs of sleep dysfunction. If you're finding it hard to sleep, you might want to try different ways to distract your mind from focusing on the light. This could include breathing techniques or relaxing audiobooks. At night you remove the rest of the light in your field of vision and the visual snow symptoms may seem more prominent. Focusing on the light spots is more likely to worsen any insomnia. For anyone suffering with visual snow-related sleep deprivation, you should consult your doctor.

LETTER of the MONTH

HISTORIC SNAPS

Dear **HIW**,
People take photographs for different reasons, but what was photography first produced for?
Aurelie Palcau

Photography has transformed significantly in the last 150 years or so. The earliest photographs, taken in the 1830s, were actually used by painters. Instead of sketches that painters could later use to produce lifelike artwork, photography became the replacement study. Portrait photography was a common use of the first cameras, and soon this became a replacement for family and individual portrait painters. However, the earliest cameras were much slower than today's, meaning that the photographer's subjects were required to stay still for many minutes. By the 1840s, the exposure time of cameras had already been reduced from 20 minutes to about 20 seconds.

The camera obscura was the first camera invented

WIN!

AN AMAZING PRIZE FOR LETTER OF THE MONTH

DISGUSTINGLY DELICIOUS

If you think eating broccoli or anchovies sounds unappealing, just wait until you hear what's on the dinner table around the world

ENERGY DRINK CHEMISTRY

Dear **HIW**,
What are the ingredients in energy drinks?
Tyrone Corson

Most energy drinks contain caffeine, glucuronolactone and taurine, which form part of an 'energy blend'. Caffeine is a natural brain and central nervous system stimulant that is extracted from tea, coffee or cacao plants. Taurine is an amino sulphonic acid that occurs at lower levels naturally in the body to support nerve growth. Glucuronolactone is also a chemical that's usually found in low levels in the body's connective tissues and is linked to alertness. The toxicity of many of the chemicals in energy drinks are unknown, so they are banned or age restricted in multiple countries.

There are over 190 energy drink brands

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A jellyfish can survive for 48 minutes out of water as long as it remains damp

STRANDED JELLIES

Dear **HIW**,
You always see jellyfish washed up on beaches, and they can still sting you. Does this mean some of them are still alive?
Dani W

Unfortunately, as soon as jellyfish leave the water they start to die very quickly. This is because they rely on the oxygen that they take in from the surrounding seawater in order to breathe. Jellyfish also dehydrate in the wind and sunlight. Although they're dead, jellyfishes' stinging cells – called nematocysts – maintain their stinging abilities for as long as the tentacles remain damp. These cells contain toxins that are released when you touch them. To do this, nematocysts fill with water and burst when the surface detects pressure.

Space junk refers to human-made objects that no longer serve their purpose

RETURN TO EARTH

Dear **HIW**,
What determines when space junk eventually falls back to Earth? Is it due to collisions with rarefied air molecules?
Stephen

The time it takes is determined by the altitude it's orbiting Earth at. Typically, any debris that's below 372 miles will fall back to the planet within several years. This is increased to centuries when the altitude is over 497 miles. At 621 miles or more, space junk will usually remain in space for at least a thousand years. You're right in that this is due to the density of air molecules. At lower altitudes, the air becomes more dense, creating drag that slows down the orbital speed. Eventually, junk is pulled into Earth's atmosphere, burning up in the process.

WE ASKED YOU

This month on social media, we asked you: How do you think AI will change the future?

@RAFF_WILL508

Can be good or bad depending on how it is adapted and used

@MERLE.HAHA

Only a human can truly express imagination

JACOB C

I think it will take off

@RAK.MALIGE

Upskilling everyone on how to use AI is a priority as the people who know how to use AI win

@????FATEMEH????

We will be trapped in the matrix and live in an AI world

MAIA E

Worried that it will be better at my job than I am!

© Getty

HOW IT WORKS

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Amazing trivia that will blow your mind

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269,000 TONNES

A huge amount of rubbish floats on the surface of our oceans

99 DAYS

The average UK driver will spend more than three months in traffic jams over their lifetime

18 metres

Prehistoric shark Megalodon was three times as long as the biggest recorded great white shark

99.999%

The cosmic microwave background is responsible for the vast majority of radiation in the universe

Earth's core is made almost entirely of iron and nickel

ONCE EVERY 375 YEARS

On average, a solar eclipse is unlikely to be visible from your location during your lifetime

2.3 BILLION YEARS

The Sun will boil away Earth's oceans within a few billion years

42 SECONDS

The world record for removing and replacing a car engine was set in 1985

CATHOLIC PRIEST GEORGES LEMAÎTRE WAS FIRST TO PUT FORWARD THE BIG BANG THEORY

© Getty

IF I HAD SOMEWHERE TO LIVE...

I COULD GO ANYWHERE IN LIFE

When Abi's mum died, life got tough. She didn't get on with her dad and the arguments became violent. Abi felt her only choice was to leave home. With just the clothes on her back, and no idea where to go, she ended up sleeping on the streets in the freezing cold.

Right now, you could give a homeless young person like Abi somewhere to start their future

Abi's life changed when she was given a room at Centrepoint. A safe place to sleep and recover. A place to develop the skills and confidence she needed to rebuild her life – and leave homelessness behind for good. Now, Abi believes she can go anywhere.

Thousands of homeless young people like Abi are desperately trying to find their place in the world – but first they need a place to start again. **You could help right now by sponsoring a room at Centrepoint for just 40p a day.**

We know this support changes lives. 88% of the young people we help move on positively in life. So please, help someone like Abi today. Thank you.

Text PLACE to 78866 to donate £3
Call free on 0800 472 5798
Visit centrepoint.org.uk/place
Or complete and return the form below

SPONSOR A ROOM. HELP A HOMELESS YOUNG PERSON FIND THEIR PLACE.

YES, I WANT TO SPONSOR A ROOM FOR £12 A MONTH

Please collect my payment on the 1st/15th of every month (please circle preferred date).

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To the Manager:
Name and full address of your Bank or Building Society:

Originators Identification No. 6 5 9 1 0 7

_____ Postcode _____

Name(s) of Account Holder(s) _____

Bank Sort Code: ☐☐-☐☐-☐☐ Account Number: ☐☐☐☐☐☐☐☐

Instructions to your Bank or Building Society: Please pay Centrepoint Direct Debits from the account detailed in this instruction, subject to the safeguards assured by the Direct Debit Guarantee. I understand that this instruction may remain with Centrepoint and, if so, details will be passed electronically to my Bank/Building Society.

Signature(s) _____ Date _____

Banks and Building Societies may not accept Direct Debit Instructions for some types of account.

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Your name and address are needed to identify you as a current UK taxpayer.

Your donation will go towards funding Centrepoint's vital work with young people all year round providing accommodation and support. We sometimes use models and change the names of the young people we work with to protect their identity; however all stories are true and as told by the young person.

Full Name: _____
Address: _____
Postcode: _____ Telephone: _____
Email: _____

Thank you for donating to Centrepoint today.

We'd love to show the impact of your support and share how young people continue to need your help, through newsletters, fundraising appeals and information about events. Please let us know how best to stay in touch with you by adding your details above, and ticking the relevant boxes:

☐ **Please contact me by email** ☐ **Please contact me by phone**

Last year our supporters helped us change the lives of over 15,000 homeless young people. By letting us know we can count on you, we can continue helping young people with a home and a future.

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Please return this form to: Freepost Plus RTXY-LBEA-UTJJ, Angel Fulfilment Services Ltd, Communication Centre, Par Moor Road, Par PL24 2SQ.

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